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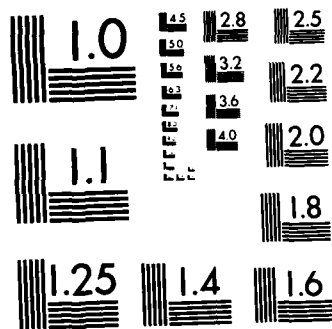
ANNUAL PROGRESS REPORT FISCAL YEAR 1982(U) ARMY  
RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA  
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REPORT NO. RCS-MEDDH-288(R1)

US Army Research Institute of Environmental Medicine

ANNUAL PROGRESS REPORT

Fiscal Year 1982

(1 October 1981 - 30 September 1982)

**U S ARMY RESEARCH INSTITUTE  
OF  
ENVIRONMENTAL MEDICINE  
Natick, Massachusetts**

1 October 1982



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**UNITED STATES ARMY  
MEDICAL RESEARCH & DEVELOPMENT COMMAND**

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1. REPORT NUMBER RCS-MEDDH-288(R1)	2. GOVT ACCESSION NO. AD A139 012	3. RECIPIENT'S CATALOG NUMBER												
4. TITLE (and Subtitle) US Army Research Institute of Environmental Medicine Annual Progress Report FY82		5. TYPE OF REPORT & PERIOD COVERED Annual Progress Report 1 Oct 1981 - 30 Sep 1982												
		6. PERFORMING ORG. REPORT NUMBER												
7. AUTHOR(s) ERNEST M. IRONS, JR., COLONEL, MSC		8. CONTRACT OR GRANT NUMBER(s) 6.11.01.A 3A161101A91C 00 6.11.02.A 3M161102BS10 00												
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research Institute of Environmental Medicine, Natick, Massachusetts 01760		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 6.27.34.A 3S162772A875 00 6.27.77.A 3E162777A878 00 6.27.77.A 3E162777A879 00												
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Medical Research and Development Command, Fort Detrick, Frederick, MD 21701		12. REPORT DATE 1 October 1982												
		13. NUMBER OF PAGES 399												
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified												
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE												
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.														
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)														
18. SUPPLEMENTARY NOTES														
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)														
<table border="0"> <tr> <td>Acute Mountain Sickness</td> <td>Altitude Acclimatization</td> <td>Bile</td> </tr> <tr> <td>Aerobic Fitness</td> <td>Anaerobic Power</td> <td>Biofeedback</td> </tr> <tr> <td>Air Ions</td> <td>Angiography</td> <td>Biometeorology</td> </tr> <tr> <td>Altitude</td> <td>Antidote</td> <td>Blood Coagulation</td> </tr> </table>			Acute Mountain Sickness	Altitude Acclimatization	Bile	Aerobic Fitness	Anaerobic Power	Biofeedback	Air Ions	Angiography	Biometeorology	Altitude	Antidote	Blood Coagulation
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Aerobic Fitness	Anaerobic Power	Biofeedback												
Air Ions	Angiography	Biometeorology												
Altitude	Antidote	Blood Coagulation												
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A report of progress on the research program of the US Army Research Institute of Environmental Medicine for Fiscal Year 1982 is presented as follows:														
Program No.	Project No.	Task No.	Title											
6.11.01.A	3A161101A91C	00	In-House Laboratory Independent Research											
6.11.02.A	3M161102BS10	00	Defense Research Sciences, Army											
6.27.34.A	3M162734A875	00	Tolerance and Toxicity to CW Agents and Antidotes											
6.27.77.A	3E162777A878	00	Health Hazards of Military Materiel											
6.27.77.A	3E162777A879	00	Medical Factors Limiting Soldier Effectiveness,											

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Body Weight Regulation  
Catecholamines  
Cerebral Function  
CIVD  
Classical Conditioning  
Climatic Exposure  
Cognitive Function  
Cold Injury  
Coronary Artery Disease  
Coronary Risk Index  
CW Agents  
Dehydration  
Disabilities  
Electroencephalography  
Endothelial Cells  
Endotoxin  
Energy Expenditure  
Environmental Comfort  
Environmental Medicine  
Environmental Stress  
Environmental Tolerance  
Ergometry  
Evaporative Cooling Index  
Exercise Capacity  
Fitness Evaluation  
Frostbite  
Health Risk Factors  
Heat Disability  
Heat Stress  
Heat Stroke  
Heat Tolerance  
Hepatic Necrosis  
Hypobaric Hypoxia  
Hypothermia  
Hypovolemia  
Hypoxia Tolerance  
Insulation  
Job Performance  
Maximal O<sub>2</sub> Uptake  
Meditation Techniques

Mental Fatigue  
Military Operations  
Military Tactics  
Moisture Permeability Index  
Motivation  
Muscle Fatigue  
Muscle Fibers  
Muscle Strength  
Obesity  
Pathology Model  
Platelets  
Performance Limits  
Peripheral Blood Flow  
Physical Fitness  
Physical Training  
Protection  
Psychomotor Performance  
Pulmonary Artery Hypertension  
Pulmonary Edema  
Pupillometry  
Questionnaires  
Rating Scales  
Survey Analysis  
Sustained Operations  
Team Performance  
Terrain Coefficient  
Thermal Exchange  
Thermogenesis  
Thermography  
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Thyroid  
Tissue Culture  
Tolerance Prediction  
Training Injuries  
Transaminases  
Vasodilatation  
Ventilation  
Ventilatory Muscles  
Ventilatory Acclimatization  
Work Capacity

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3. DATE PREV SUMMARY <sup>a</sup>	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
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C. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U) Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 007900 Occupational Medicine; 012500 Personnel Selection Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
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19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
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NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> SAMPSON, JAMES B., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4855			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: KOBRICK, JOHN L., Ph.D..			
				POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U) Survey Analysis; (U) Self-Reports; (U) Questionnaires/Interviews; (U) Climatic Exposure; (U) Health Risk Factors; (U) Rating Scales							
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Current medical records do not adequately define the number and type of Army personnel who suffer environmentally-induced illness and injury. Data must be obtained on the population at risk, on treatment follow-up, on partially disabling symptoms which go unreported, on the nature of exposure, and on medical risk factors due to job assignment, individual background, physical condition, and related health behaviors.</p> <p>24. (U) This work unit develops and pilot tests new methods for survey sampling and epidemiologic studies of Army personnel exposed to specific climatic extremes and physical demands in training exercises. Questionnaires, structured interviews, personnel and medical record survey forms and symptoms, incapacitation, illness and injury under specific Army environmental conditions are designed, sample tested, revised and validated for subsequent routine use in other work units.</p> <p>25. (U) 81 10 - 82 09 Revised Medical Record log books and modified interview forms, developed for the purpose of simplifying collection of personnel data, were found to be effectively processed by a newly developed field computer system. This instrumentation and further refinements to improve reliability and validity of survey data are judged now to have progressed sufficiently to be applicable to Project S10 objectives now underway; therefore, ILIR Work Unit 020 is terminated.</p>							

<sup>a</sup> Available to contractors upon originator's approval

Program Element: 6.11.01A IN-HOUSE LABORATORY INDEPENDENT  
RESEARCH  
Project: 3A161101A91C In-House Laboratory Independent Research  
Work Unit: 020 Development of Survey Methodology for Analysis of  
Environmental Medical Illness and Risk  
Study Title: Analysis of Factor Structures of Symptomatology at  
Outpatient Clinics During Cold Weather Maneuvers  
Investigators: James B. Sampson, Ph.D. and John L. Kobrick, Ph.D.

Background:

Research methods of environmental medicine involve experimental studies which are valuable and necessary for answering important questions of basic mechanisms and processes of climatic stress. However, the experimental techniques which call for careful control of many variables are difficult to implement when trying to assess problems during military operations. Field research requires different methodology because of the lack of sufficient controls. An alternative is to rely on existing records to extract information on medical problems occurring in conditions of extreme weather. However, this too has limitations. Current medical records do not adequately define the number and type of Army personnel who suffer environmentally-induced illness and injury. Data are usually lacking on the population at risk, on treatment follow-up, on partially disabling symptoms which go unreported, on the nature of exposure, and on medical risk factors due to job assignment, individual background, physical condition, and related health behaviors. A third alternative develops and tests new methods for survey sampling and epidemiologic studies of Army personnel exposed to specific climatic extremes and physical demands in training exercises. Questionnaires, structured interviews, personnel and medical record survey forms and observation procedures can be used to collect subjective and objective data regarding exposure, symptoms, incapacitation, illness, and injury under specific conditions. These survey instruments must be designed, sample tested, revised, and validated for subsequent routine use in other work units.

Progress:

A new version of the Environmental Symptom Questionnaire (ESQ) was administered at random to Army personnel who reported to medical treatment facilities during two cold weather maneuvers (Alaska and New York). A total of 374 questionnaires were completed by people with the following primary complaints: Orthopedic (32.9%); Respiratory Infection (17.19%); Dermatological (9.4%); Ear, Eye, Nose and Throat (9.4%); Gastrointestinal (7.5); and Adverse Weather Injury (6.4%). Factor analysis of the questionnaire was run using principal component analysis and varimax rotation. The results gave ten factors labeled as follows: "Sick", "Respiratory Infections", "Psychological", "Cold", "Circulation", "Gastrointestinal", "Respiratory Distress", "Muscular Stress", "Ear Discomfort", and "Visual Disturbance". Items for each factor show high content validity and clear demarcation. Factor 1, "Sick", accounts for 52.1% of the total variance. Future analysis will attempt to evaluate the ability of these factors to reliably classify the type of illness being recorded. ESQ factor scores will be applied to future studies to determine their diagnostic value in assessing the effects of heat, cold and other environmental stresses.

FOR REVIEW

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B. CONTRIBUTING						021	
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11. TITLE (Precede with Security Classification Code) <sup>a</sup>							
(U) Exercise Tolerance at Altitude (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup>							
012900 Physiology; 005900 Environmental Medicine; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
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17. CONTRACT: GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
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B. NUMBER: <sup>a</sup>				FISCAL		82	
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E. KIND OF AWARD:				83		1.5	
F. CUM. AMT.						63	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
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RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
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TELEPHONE: 256-4811				TELEPHONE: 256-4852			
				SOCIAL SECURITY ACCOUNT NUMBER			
21. GENERAL USE				ASSOCIATE INVESTIGATORS			
Foreign Intelligence Not Considered				NAME: LEITH, DAVID E., M.D. POC:DA			
				NAME:			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Human Volunteer; (U)Loaded Breathing; (U)Exercise Performance; (U)Ventilatory Muscle Endurance Training							
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) At high terrestrial altitudes or in the presence of incapacitating chemical or biological agents, soldiers must wear protective devices which add resistive loads to breathing. Added inspiratory resistance decreases exercise tolerance and, therefore, may limit the effectiveness of military operations in hostile environments. The objective of this work unit is to: (a) explore the little-understood mechanisms of work limitation due to loaded breathing and (b) test two related hypotheses: (1) that ventilatory muscle fatigue contributes to the performance impairment due to loaded breathing and (2) that ventilatory muscle endurance training will minimize the decrement in exercise tolerance.</p> <p>24. (U) Exercise tolerance will be measured during exercise with and without added resistance to inspiration. Related physiological variables including heart rate, ventilation, gas exchange, and end-expired carbon dioxide concentration will be recorded continuously up to the exercise breakpoint. Preliminary studies will be necessary to select exercise regimes most sensitive to added resistances.</p> <p>25. (U) 81 10 - 82 09 Methods and procedures for calibration, validation and data reduction were developed. This includes the planned transition from batch measurement of expired gas volume and composition with hand calculations, to a computerized on-line-system using a specially-written program for a MINC-11 computer. A small but sophisticated pulmonary function testing laboratory was set up for measuring not only routine functions but also ventilatory muscle strength and endurance. The latter is measurable with and without inspiratory resistive loading and includes recording of inspiratory and expiratory pressures and timing as well as rate and depth of breathing. Military volunteer subjects have been recruited, and the definitive experiments are underway.</p>							

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 021 Exercise Tolerance at Altitude

Study Title: Does Inspiratory Muscle Training Improve Exercise Tolerance during Loaded Breathing?

Investigators: David E. Leith, M.D., Howard G. Knuttgen, Ph.D., Allen Cymerman, Ph.D., Ronald A. Gabel, M.D. and Vladimir Fenc1, M.D.

#### Background:

Exercise tolerance is decreased by added inspiratory resistance (R)(1-8). Inspiratory muscle (IM) fatigue may be a contributing factor (9-18). IM endurance can be increased by specific training (13, 19-21). This study tests the hypothesis that IM endurance training (IMET) will minimize or prevent the decrement in exercise tolerance due to R, and explores the little understood mechanisms of work limitation due to loaded breathing.

#### Progress:

The project is on schedule and proceeding well. We have completed the development and validation of methods, standardized the protocol and procedures, and prepared computer programs for data management. Six subjects are now completing the two-month protocol, and initial tests are partially analyzed. Initial (pre-training) studies in six subjects confirm and extend published experience with exercise limitation due to loaded breathing (1-11). Added resistance to inspiration  $P_{res} = k\dot{V}^2$ , where  $k=9\text{cm H}_2\text{O}/(\text{L}/\text{sec})^2$  decreases ventilation and increases end-tidal  $P_{\text{CO}_2}$  at all work loads. It consistently decreases maximum tolerable exercise intensity, usually by 50 watts, (Fig. 1) which is two power increments and 6 minutes in our progressive cycle ergometer test, which starts at 100 watts and ends with exhaustion. Despite the marked increase in respiratory muscle power, no change in  $\dot{V}\text{O}_2$  or  $\dot{V}_{\text{CO}_2}$  is detectable (Fig. 2). Adding R causes decreased respiratory frequency, partially compensated by increased tidal volume; it increases the time fraction spent in inspiration but drastically reduces mean inspiratory flow. We are now

analyzing the relationships between individual subjects' ventilatory muscle capacities and their responses to exercise and to loading.

We do not yet have enough information to comment on the effects of the training programs.

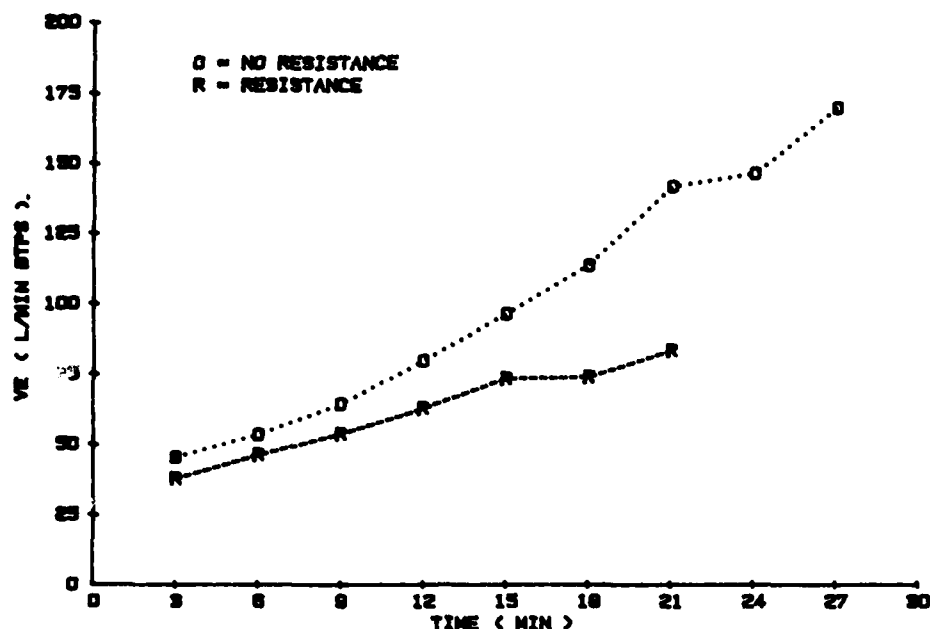


Figure 1. Ventilatory response to progressive exercise starting at 100 W and increasing by 25 W every 3 min. Adding resistance ( $9\dot{V}\text{cmH}_2\text{O/L/sec}$ ) decreases  $\dot{V}_E$  and peak exercise tolerance.

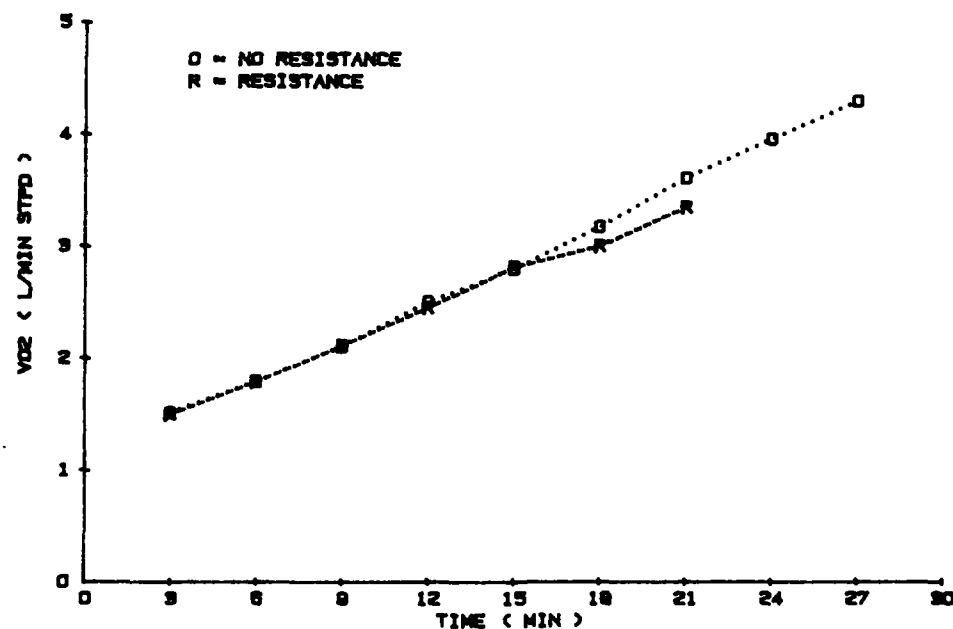


Figure 2.  $\text{O}_2$  consumption during progressive exercise to exhaustion. Adding resistance does not change  $\dot{V}\text{O}_2$  at any given work load.

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FOR REVIEW

(023)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL	
				DAOG 1299	82 09 30	DD-DR&E(AR)636	
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISSEM INSTR <sup>a</sup>	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
82 04 30	D.CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO./CODES: <sup>a</sup> PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
a. PRIMARY		61101A		3A161101A91C		00 023	
b. CONTRIBUTING							
c. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U) Assessment of Psychological Intervention Techniques as Prophylaxes or Treatments for Environmentally-Induced Illnesses.							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 0134000 Psychology 016200 Stress Physiology 012500 Personnel Selection, Training and Evaluation.							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
81 04		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING		b. FUNDS (In thousands)	
b. NUMBER: <sup>a</sup>				FISCAL		82 0.5 50	
c. TYPE:				YEAR		CURRENT	
d. AMOUNT:				83		1.5 80	
e. KIND OF AWARD:				f. CUM. AMT.			
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> Natick, MA 01760				ADDRESS: <sup>a</sup> Natick, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
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21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: <sup>a</sup> SAMPSON, JAMES B., Ph.D.			
				NAME: <sup>a</sup> KOBRICK, JOHN L., Ph.D. POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) <sup>a</sup> (U) Behavior Medicine; (U) Classical Conditioning; (U) Biofeedback; (U) Meditation techniques.							
23. (U) TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.) 23. (U) The field of Behavioral Medicine has demonstrated that many body functions controlled by the autonomic nervous system can be influenced by (a) classical (Pavlovian) conditioning, (b) "Biofeedback", (c) training in progressive muscular relaxation ("autogenic training"), (d) "self-hypnosis", (e) a variety of meditation techniques. Skin temperature (i.e., local blood flow) has been shown to be a controllable function by all of these techniques. Classical conditioning has been reported effective (in a small pilot study) for decreasing cold hypersensitivity in patients with Raynaud's phenomenon. The initial objective of this work unit is to assess the technical feasibility of using such psychological interventions to reduce the peripheral vasoconstriction which occurs during cold exposure. This would have direct military value in increasing the performance effectiveness (e.g., manual dexterity) of troops in the cold and in reducing the risk of frostbite and trenchfoot, (both capable of producing permanent disability). The techniques may also be effective in reducing the high risk of recurrence in soldiers who have already suffered cold injury, many of whom now have profiles which limit their reassignment to missions in cold weather. Those behavioral intervention techniques which are demonstrated effective in these laboratory studies will be further refined under applied work units and will be tested for reliability and practicality on Army troop populations under realistic garrison conditions. 24. (U) Research funded under DAOG 6332 established that classical reconditioning techniques were effective in increasing hand temperature. 25. (U) 81 10 - 82 09 An approved study to compare the cold responses of cold hypersensitive, normal, and previously frostbitten individuals is presently being implemented. A second approved study to evaluate the relative effectiveness and persistence of biofeedback, relaxation, and conditioning techniques for management of cold hypersensitivity is in the planning stages.							

<sup>a</sup> Available to contractors upon originator's approval.DD FORM 1498  
1 MAR 66

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 66 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 023 Assessment of Psychological Intervention Techniques as Prophylaxes or Treatments for Environmentally Induced Illnesses

Study Title: Induced Peripheral Vasodilation in Cold by Classical Conditioning

Investigators: Jared B. Jobe, CPT, MSC, Ph.D., James B. Sampson, Ph.D., Donald E. Roberts, Ph.D. and William P. Beetham, Jr., M.D.

Background:

Research in behavioral medicine has shown that many automatically-mediated body functions can be brought under conscious control through behavioral intervention techniques such as biofeedback, self-hypnosis and meditation. Local blood flow in the extremities, as reflected by skin surface temperature, has been shown to be consciously controllable by individuals through training in each of these techniques. Such research has important ramifications for the military inasmuch as a majority of all individuals are hypersensitive to the cold and are, therefore, at greater risk to frostbite injury.

The most widely known method of behaviorally increasing blood flow to the hands is biofeedback, involving operant conditioning (e.g., Roberts, Kewman & MacDonald, 1973). Vasodilation via biofeedback has also been successfully demonstrated in a cooling environment (e.g., Taub, 1977). Attempts to apply these procedures to Raynaud's patients have been moderately successful, with some studies combining biofeedback with other treatment modes.

Surwit (1973) reported five case studies of Raynaud's patients in which biofeedback was employed along with other behavioral methods. The results were generally successful, although Surwit rightfully concluded that it was not possible to determine whether biofeedback was the sole agent responsible for the patients' improvement. Taub (1977), with three Raynaud's subjects, found results ranging from large changes in skin temperature to very small changes. Similar results were reported by others.

Hypnosis and relaxation are other behavioral therapies that appear to be promising as treatments for vasoconstrictive syndromes. Jacobson, Hackett, Surman and Silverberg (1973) found small changes in skin temperature using

hypnosis combined with feedback; hypnosis alone produced no change. Additionally, Grabert, Bregman and McAllister (1980) found that feedback plus suggestion produced increases in skin temperature, although neither method by itself was effective.

Marshall and Gregory (1974), using classical conditioning, found much larger changes in skin temperature than did the other studies. Eight cold hypersensitive subjects, three of whom exhibited idiopathic Raynaud's disease, were given six pairings of a whole-body-cold stress of 0°C (conditioned stimulus) and a mild heat stress to the hands of 42°C (unconditioned stimulus).

#### Progress:

The purpose of this project is to determine which behavioral method of increasing peripheral vasodilation in cold is most applicable for the military. S.L.A. Marshall and other military historians have documented and emphasized repeatedly the high incidence of casualties in winter military campaigns, such as the Korean War, which were due solely to cold exposure rather than to wounds or other battle injuries. Practical and effective techniques for reducing the risk of cold injury to military personnel would have direct military value by increasing performance effectiveness and reducing the risk of frostbite and trenchfoot, both of which can be permanently disabling. An initial study, conducted in FY81, which investigated classical conditioning of peripheral bloodflow on a large number of subjects, found classical conditioning to be an effective treatment for cold hypersensitivity. Papers were submitted and presented at the New England Rheumatism Association Conference in Dedham, MA in May and at the Pan American Congress of Rheumatology Conference in Washington, DC in June. A manuscript was accepted for publication in Annals of Internal Medicine. In addition, news articles will appear in Current Rheumatology and in Skin and Allergy News.

A second study consisting of two experiments is currently in progress and is comparing classical conditioning therapy not only with biofeedback, but also with relaxation therapy for individuals with cold hypersensitivity and Raynaud's disease. Classical conditioning treatments consist of 54 ten-minute simultaneous pairings of hand immersion in warm water (43°C) with whole body exposure to cold (0°C). Biofeedback treatments consist of 18 one-hour sessions of electromyograph or thermal feedback paired with relaxation audio tapes. Relaxation treatment consists of 18 one-hour sessions of relaxation audio tapes.

Another collaborative study with the Dartmouth Medical School, Hanover, NH will evaluate classical conditioning as a treatment for individuals with Raynaud's disease which is the result of a digital frostbite injury.

A related study compared the digital cold response to cold water immersion of individuals with Raynaud's disease with the digital cold response of normals. Subjects immersed the middle finger of their left hand in a circulated water bath at either 5°, 10°, or 15°C for 15 minutes. Results indicated that individuals with Raynaud's disease took longer to initiate a cold induced vasodilation (CIVD), had lower overall temperatures during the immersion, and showed a less pronounced CIVD.

A protocol has been approved for future work, evaluating the classical conditioning therapy using home treatment.

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FOR REVIEW

(024)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL	
				DA OC 6125	82 09 30	DD-DR&E(AR)636	
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
82 04 30	D. CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO./CODES*		PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER	
A. PRIMARY		61101A		3A161101A91C		00	
B. CONTRIBUTING						024	
C. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code)*							
(U) Regulation of Body Weight (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012400 Personnel selection and maintenance (medical); 012900 Physiology; 003500 Clinical medicine							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
77 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PRECEDING		B. FUNDS (In thousands)	
B. NUMBER:				82		1.0	
C. TYPE:				FISCAL YEAR		19	
D. KIND OF AWARD:				83		1.0	
E. CUM. AMT.							
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME:*				NAME:*			
USA RSCH INST OF ENV MED				USA RSCH INST OF ENV MED			
ADDRESS:*				ADDRESS:*			
Natick, MA 01760				Natick, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
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TELEPHONE: 256-4811				TELEPHONE: 256-4832			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: DANFORTH, E.(U of VT Med School)POC:DA			
				NAME: PIMENTAL, NANCY A., M.P.H.			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Fitness; (U)Body Weight Regulation; (U)Obesity; (U)Catecholamines; (U)Thermogenesis; (U)Thyroid; (U)Human Volunteer							
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code)							
<p>23. (U) In collaboration with clinical research groups, assess the metabolic (USARIEM) and endocrine (clinical collaborators) responses of individuals with no body fat (lipodystrophy), limited body fat (anorexia nervosa and lipoatrophy), normal body fat but difficulties with weight regulation ("hard" and also "easy gainer") and excess body fat (obesity). Also develop/validate simple measures to assess body fat. Those individuals with an excessively high or low body fat content may be at increased risk of ill health, and their military appearance and performance may be adversely affected (AR 600-9).</p> <p>24. (U) Measure metabolic heat production and heat loss during exercise, pre-and post-prandial rest and basal conditions of individuals on normal high and low caloric intake levels, with varied proportions of dietary carbohydrate, fat and protein, while measuring endocrine responses, with attention to thyroid regulation of body heat production and, consequently, body weight.</p> <p>25. (U) 81 10 - 82 09 Experimental data collection this year has focused on the in-house measurements of body composition utilizing hydrostatic weighing techniques and skinfold measurements. Reliability was determined for repeated measurements of percent body fat as calculated from hydrostatic weighings, both day-to-day and within day. Over 200 subjects have had their body composition assessed by hydrostatic weighing and skinfold measurements: females ranging in body fat from 14 to 39%, and males ranging from 4 to 29%. Groups include males and females participating in a dehydration study, 16 females pre and post a physical training program with controlled diet (collaboration with Harvard Med School and Boston Univ), males participating in water immersion studies, and a select group of male body builders and weight lifters who may have unique body composition characteristics. As a group, the body fat for the females was determined to be 25.7% as calculated from hydrostatic weighing and 27.5% from skinfold measurements. As a group, the males were 16.1% from hydrostatic weighing and 17.2% from skinfolds. There appears to be better agreement between the two techniques for individuals of average body fat and there appears to be better agreement for certain age groups.</p>							

DD FORM 1498

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 66 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 024 Regulation of Body Weight

Study Title: Evaluation of Fitness Reference Standards of Body Composition

Investigators: Nancy A. Pimental, M.P.H., Richard L. Burse, Sc.D., Ralph F. Goldman, Ph.D. and Kent B. Pandolf, Ph.D.

Background:

Current Army Regulations (AR 600-9) discuss the relationships between height, weight, military appearance and physical fitness of the soldier (1). Those individuals who do not meet stated weight standards (after goals have been established but not met) could receive unfavorable evaluation reports, unfavorable remarks in their official military personnel file, or receive a bar to re-enlistment, or may even be discharged from the Army. While the use of such height-weight tables is often sufficient, for some individuals the use of weight alone as an indicator of fitness may be misleading. These individuals include those who have a very high muscle mass or those who are fit but who have large uniquely located fat deposits which are genetically determined. It might be unrealistic, indeed in some cases physically hazardous, to expect weight losses as indicated by AR 600-9 in these soldiers.

It is therefore desirable to use an alternative method to evaluate fitness and establish weight goals for the soldier. Such a method should give information as to the body composition of the subject in order to separate the above described individuals from the merely overweight. This can be done by the use of skinfold assessment (2) or hydrostatic weighing to estimate total body fat content.

The purpose of this ongoing study is to measure initial amounts of body fat and monitor changes in body fat in those soldiers who do not meet current Army weight goals. Hydrostatic weighing to determine body density and estimate percent body fat will be performed in cases where skinfold assessment is considered inappropriate or unacceptable. Collected data is given to the Medical Officer for use in prescribing diet and/or exercise programs.

Progress:

During FY82 no military person was referred for skinfold assessment of body fat by the Medical Officer at Natick Labs. Seven males who appeared fit but approached or exceeded their maximum weight as established by AR 600-9 had % body fat estimated by hydrostatic weighing. Their data is presented in Table 1. Their ages ranged from 25 to 35 years, height from 65 to 75 inches, and weight from 173 to 276 pounds.

TABLE 1

Subject	Age	Height (inches)	Weight (pounds)	Maximum Allowable Weight	Average % Fat for Age Group	Actual % Fat
1	29	65.2	181	166	15	11.5
2	35	70.9	204	197	23	13.2
3	32	68.5	181	183	23	14.5
4	31	68.4	181	183	23	18.6
5	25	67.7	173	180	15	14.8
6	27	68.7	177	185	15	15.1
7	34	74.5	276	217	23	29.2

Subjects 1 and 2 exceeded their maximum allowable weights. Subject 1 exceeded his maximum weight by 15 pounds although his % body fat of 11.5 was well below average for his age group. The second subject was 7 pounds over his maximum weight, yet his body fat is a dramatic 10% lower than the average for his age. Subjects 3 and 4 were 8% and 4%, respectively, below the average for their age and yet only 2 pounds below their maximum allowable weight. Subjects 5 and 6 have average % body fat for their ages; however, they were within 8 pounds of their maximum allowable weight. These subjects (#3-6) have little room for deviation even though body fats several percent higher than average might be quite acceptable. Subject 7, at 276 pounds, is 59 pounds over his maximum allowed by AR 600-9. Although he is 6% higher than average in body fat, to reduce to 217 pounds would be unreasonable: this would make him only 10% body fat, although average for his age group is 23%. With his lean body

mass of 195 pounds, if he were to lower his body fat to the average for his age, his goal weight would be 254 pounds. This is still 37 pounds over the maximum allowed. To expect him to reduce to 217 pounds could prove to be hazardous to his health. For subjects 1 and 2, who were extremely muscular and fit, to lose weight might cause a decrement in strength. Data measured on these 7 subjects demonstrate the appropriateness of a revised military standard for weight based upon percent body fat.

#### LITERATURE CITED

1. AR 600-9, The Army Physical Fitness and Weight Control Program. HQ, Department of the Army, Washington, DC, November 1976.
2. Durnin, J.V.G.A. and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br. J. Nutr. 32:77-97, 1974.

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH  
Project: 3A161101A91C In-House Laboratory Independent Research  
Work Unit: 024 Regulation of Body Weight  
Study Title: Estimation of Percent Body Fat by Two Methods: Hydrostatic Weighing and Skinfold Measurements  
Investigators: James E. Bogart and Nancy A. Pimental, M.P.H.

Background:

The first purpose of this study was to validate this Military Ergonomics Division's hydrostatic weighing system with respect to apparatus and procedure. The system had been renovated and set up in Room 024A, USARIEM, in October of 1980. The second purpose of the study was to determine the degree to which differences may occur between % body fat estimates by hydrostatic weighing as compared with skinfold measurements.

Progress:

The original Waters nitrogen analyzer has been replaced by a new Collins nitrogen analyzer. After renting a Collins analyzer for several months to test its performance, one was purchased which operates much faster than the original Waters. The formulas to convert raw data to values for residual volume, body density and % body fat have been programmed on the Hewlett Packard 85 computer to expedite data calculation. One more individual was trained to instruct subjects during the hydrostatic weighing procedure.

An original group of 15 male subjects (mean  $\pm$  SD age =  $19.9 \pm 1.0$  yr, height =  $176 \pm 5$  cm, weight =  $71.5 \pm 7.3$  kg) was tested on two consecutive days to determine the reliability of the hydrostatic weighing system. The standard deviation of the difference distribution for replicate determinations of body density was calculated. The value of 0.0015 was well below the value of 0.0025 cited by Siri as acceptable, and compared favorably with the results of other investigators (1). Body fat on these 15 subjects ranged from 4 to 23%. The mean ( $\pm$  SD) for the first test was  $14.4 \pm 4.3\%$ , and for the second test was  $14.8 \pm 4.0\%$ . These values were not significantly different ( $p > 0.05$ ). We conclude that the current hydrostatic weighing system provides a reliable method for estimating % body fat.

During FY 82 we performed 77 hydrostatic weighings, 25 on females and 37 on males (15 subjects were tested on two occasions). A detailed description of the results of 7 of these hydrostatic weighings has been included in this Annual Progress Report. To date, 215 hydrostatic weighings have been performed on both military and civilian personnel. This total included 46 females whose body fat ranged from 14 to 39%, and 77 males whose body fat ranged from 5 to 29%. Percent body fat as estimated by hydrostatic weighing was compared to percent fat as estimated by skinfold measurement (2). For the females, mean % body fat ( $\pm$  SD) by hydrostatic weighing was  $25.7 \pm 5.3$  and by skinfolds was  $27.5 \pm 4.4$ . For the males, % body fat by hydrostatic weighing was  $15.8 \pm 4.9$  and by skinfolds was  $16.8 \pm 4.8$ . Paired t tests revealed % body fat by skinfold assessment to be significantly higher than by hydrostatic weighing for both females and males (females,  $p < 0.001$ ; males,  $p < 0.01$ ). These data indicate that body fat assessment by skinfold measurements may have some usefulness in describing subject populations, however they should not replace the use of hydrostatic weighing when % body fat is an important aspect of data interpretation.

Future modifications of the current hydrostatic weighing system may include a pen recorder to be attached to the electronic scale measuring the weight of the test subject in the water tank. A pneumatic valve for switching from the snorkel to the rebreathing bag may be added. This protocol was closed at the end of FY82. However, the hydrostatic weighing system will remain operative in support of future Division studies.

#### LITERATURE CITED

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2. Durnin, J.V.G.A. and J. Womersley. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br. J. Nutr. 32:77-97, 1974.

FOR REVIEW

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD-DR&E(AR)636	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8. DISSEM INSTRN	9. SPECIFIC DATA- CONTRACTOR ACCESS	10. LEVEL OF SUM
82 04 30	H.TERMINATED	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
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a. PRIMARY		61101A	3A161101A91C	00		025	
b. CONTRIBUTING							
c. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code)* (U) Development of Assessment of Biometeorologic Variables and Their Influence on Health and Performance (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 007900 Occupational Medicine; 005900 Environmental Biology; Psychological; 016800 Toxicology; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
79 10		82 09		DA		C. IN-HOUSE	
17. CONTRACT GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING		0.5	
b. NUMBER:				FISCAL		21	
c. TYPE:				YEAR		83	
d. KIND OF AWARD:				CURRENT		0	
e. CUM. AMT.				0		0	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: USA RSCH INST OF ENV MED				NAME: USA RSCH INST OF ENV MED			
ADDRESS: NATICK, MA 01760				ADDRESS: NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
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TELEPHONE: 256-4811				TELEPHONE: 256-4855			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: ZISKIND, DAVID, M.A. POC:DA			
				NAME: KOBRICK, JOHN L. Ph.D.			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Biometeorology; (U)Air Ions; (U)Humidity; (U)Environmental Health; (U)Environmental Comfort (U)Human Performance							
23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Literature indicates that certain atmospheric phenomena may produce medical and psychological symptoms. Winds from deserts or mountain ranges where U.S. troops may be deployed are associated with malaise, upper respiratory and eye irritation, dyspnea, headache, impaired performance, depression, suicide, murder, accidents and absenteeism; these weather fronts involve a net excess of positive air ions which are hypothesized to trigger neuronendocrine secretion in sensitive individuals. Air ionization may account for geographical variability of acute mountain sickness at equivalent elevations. Positive air ions also reportedly cause symptoms in operators of electronics equipment in confined spaces such as Army personnel use. Tasks of critical military importance (vigilance, quick reaction and psychomotor coordinations) are reported especially sensitive. The biological effects of air ions are probably modified by ambient humidity, temperature, barometric pressure, dust, ozone or other pollutants, accounting for some contradictory research results. These variables may also be important <u>per se</u>: e.g., relative humidities outside the narrow "comfort zone" effect subjective well-being and perhaps performance and health more than are explained by the thermodynamics.</p> <p>24. (U) Potentially influential biometeorologic variables should be monitored, if not controlled, in USARIEM's laboratory and field studies of heat, cold and hypoxic (hypobaric) stress. USARIEM's environmental chambers permit systematic exploration of multiple biometeorologic variables related to USARIEM's primary mission areas. This work unit supports equipment procurement, characterization of the physical interactions of the variables in the experimental settings, and exploratory tests of behavioral and physiological effects in human volunteers and animal models.</p> <p>25. (U) 81 10 - 82 09 Data analysis in a study involving psychological performance of 50 men exposed to combinations of ambient heat and positive or negative ion concentrations was completed. No significant effects of experimental variables, either singly or in combination, were obtained, and as such do not support further efforts in this direction at the present time. Therefore, this work unit has been terminated.</p>							

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 025 Development of Assessment of Biometeorologic Variables and Their Influence on Health and Performance

Study Title: Effects of Air Ionization on Human Mood and Performance

Investigators: David Ziskind, M.A., James B. Sampson, Ph.D. and James W. Stokes, COL, MC

Background:

An extensive literature in biometeorology indicates that a number of atmospheric phenomena can influence health and efficiency besides those which directly impact on the thermodynamics or the blood oxygenation of the organism. Of special interest to the mission of USARIEM are the notorious winds from desert or mountain regions which since the late 19th century have been correlated with increased absenteeism, accident rates, murder, suicide, and hospital admissions for a variety of illnesses (1). Known regionally by different names (the hot-dry Chamsin or Sharav of the Middle East, Sirocco or Xlokk of the Mediterranean, Zonda of Argentina and Santa Ana of the S.W. United States; the warm-dry Foehn from the Alps and Chinook from the Rocky Mountains, the cold-dry Mistral of South France), these winds involve different combinations of temperature and humidity. More strikingly, the disturbances of mood and the migraine-like symptoms which affect an estimated 20% of a region's population often precedes the arrival of the temperature/humidity change by 24-48h.

The predominant theory for the syndrome described above is that the symptoms are caused by the static electrical charge of the air (which can move faster than the wind itself), specifically by a net excess of positive ions produced as electrons are "rubbed off" molecules of CO<sub>2</sub>, O<sub>2</sub>, N<sub>2</sub> when air masses flow across the barren rocks or sand (2,3). Evidence supports the hypothesis that inhalation of the positive ions triggers release of serotonin by the bronchial or alveolar cells into the blood stream of sensitive individuals (4,5). Note: claims that negative air ion generators improve subjective well-being and performance continue to be controversial.

The potential loss of operator efficiency in Army teams performing complex, critical functions (more than the relatively minor symptoms of headache, upper respiratory distress, nausea, etc.) make assessment and evaluation of this phenomenon by USARIEM important. At risk are not only troops deployed to desert regions or to south central Europe, but also those who work with electrical apparatus that produces positive air ions, or in closed artificial environments which deplete negative air ions. Local positive ionization may also contribute to the marked variability of Acute Mountain Sickness in different high mountain ranges or even in different valleys at the same altitude. Temperature, humidity (or lack of it), barometric pressure, dust and air pollutants definitely influence the concentration, mobility (size) and biological activity of air ions, but the interactions of these variables have not been systematically evaluated. USARIEM's climatic chambers provide opportunity for pilot investigations to define the magnitude of the problem, to parameterize it, and to study various ways of minimizing adverse effects on critical military performance.

#### Progress:

Data collection was completed in a study to assess the effects on psychological performances of positive and negative ion concentrations combined with hot-dry and hot-humid conditions for four-hour exposure durations. Data analysis revealed no significant changes in performance which could be attributed to conditions of air ionization. On the basis of these findings, this work unit has been terminated.

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FOR REVIEW

(026)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E(AR)b36	
3. DATE PREV SUMRY <sup>a</sup>	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8. DISB'N INSTR'N	9. SPECIFIC DATA- CONTRACTOR ACCESS	10. LEVEL OF SUM A. WORK UNIT
82 09 30	D. CHANGE	U	U	DA OG 0705	83 03 30	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
10. NO / CODES: <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER			
a. PRIMARY	61101A	3A161101A91C	00	026			
b. CONTRIBUTING							
c. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Development of Capability to Assess Psychosocial and Physiological Indices During Performance (22);							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
79 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDEING		b. FUNDS (In thousands)	
b. NUMBER: <sup>a</sup>				FISCAL YEAR		82	
c. TYPE:				CURRENT		1.0	
d. KIND OF AWARD:				83		1.5	
e. AMOUNT:						53	
f. CUM. AMT.						87	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> KOBRICK, JOHN L., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4822			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: BANDERET, LOUIS E., Ph.D.			
				NAME:			
				POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) <sup>a</sup> (U)Electroencephalography; (U)Evoked Cortical Potentials; (U)Cerebral Function; (U)Pupillometry							
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Existing psychosocial and psychophysiological measures can be adapted to USARIEM studies to give insight into performance degradation under stress and to suggest means of prevention or treatment. Interaction Process Analysis (IPA) was originally developed by Bales to classify and quantify the social interaction of individuals in groups. EEG sensory evoked potentials and cortical frequency spectra are used to provide indices of central nervous system activity and arousal. Animal models are developed to explore exposure/response relationships for extremes of environmental and other agents (e.g., CBR) not safely determinable using human subjects.</p> <p>24. (U) In consultation with laboratories using these techniques, evaluate existing methodologies and adapt them to USARIEM's special requirements, develop instrumentation and ADP capability, train personnel and conduct pilot tests.</p> <p>25. (U) 81 10 - 82 09 Previously, IPA was modified to assess social interactions during lulls within 82nd ABN Div Artillery Fire Direction Center teams during simulations of sustained combat operations. To contrast IPA trends during lulls, transcripts for periods of intense operational overloads were created and scored. Data analyses are in progress. An experimental animal model is under development to explore effects of environmental extremes and/or CBR agents on performance.</p>							

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1 MAR 66PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65  
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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 026 Development of Capability to Assess Psychosocial and Physiological Indices During Performance

Study Title: Development of Methodology for the Application of Electroencephalographic and Sensory Response Measurements to the Investigation of Individual Differences in Military Performance

Investigators: John L. Kobrick, Ph.D. and James W. Stokes, COL, MC

Background:

The purpose of this project is to investigate the feasibility of using indices of central nervous system (CNS) response to account for the large differences in performance ability between individuals engaged in important military tasks, such as artillery forward observation, surveillance, and watchkeeping. Other objectives are to discriminate critical moments in performance from neutral situations within the same individuals through differences in CNS response, and to investigate change in CNS efficiency in general due to exposure to extreme natural environments, physical fatigue and sustained operations (perhaps compounded with pharmacologic defenses against chemical warfare agents). The ability to directly relate changes in indices of CNS activity to ongoing critical military task performance would provide many advantages for medical military R & D and perhaps also for actual tactical operations. Demonstrating changes in CNS response can lead to more fundamental and theoretically significant explanations of the influence of environmental stress and operationally induced fatigue on military performance, as compared to the documentation of performance impairments alone. Those stress-sensitive CNS indicators which show satisfactory reproducibility may be used to build models of human performance under stress; findings from these models could be generalized to other tasks to predict impending action of special agents (e.g., antidotes, toxic drugs, other substances) on performance at a much more fundamental level of effect than can be accomplished through empirical performance measurement alone.

### Progress:

The primary objective of this project has been to evaluate and adapt the developed analysis programs and significant indices already derived by accomplished research in this field. The purpose is to determine whether the effects of environmental stress and sustained operations can be observed as resultant changes in CNS response.

Several other laboratories, both military and civilian, have successfully identified a variety of CNS response indices which show substantial and systematic changes directly associated with changes in operator performance and/or changes in task characteristics at the time. These are principally derived from electroencephalography (EEG), or from a category of more recent interest-sensory evoked responses (SER). Several reliable and sensitive indices and electrode locations have been used, and a number of new computer-oriented mathematical techniques based on Fourier transform analysis have been developed. These efforts focus on overall CNS output during selected epochs of performance, rather than on a search for isolated clinical signs.

From the literature on task-related EEG and SER changes and on computer analytical techniques for EEG records, several indices of potential significance have been identified for investigation at USARIEM: 1) ratio of temporal-parietal EEG activity, principally in the alpha range (1); 2) right-left hemisphere alpha dominance in verbal and motor tasks (6); 3) individual differences in lateral dominance of alpha output as related to task content (2); 4) lateral alpha asymmetry as related to reaction time for verbal and motor tasks; 5) SER component differences for critical as compared to innocuous visual and auditory signals.

In addition to the above, a comprehensive literature search was continued and extended to identify further applications and uses of sensory-evoked responses in the analysis of psychological performance--particularly as it relates to military operations and environmental stress effects. Because of additional duties resulting from the assignment of the principal investigator as Acting Director of the Health & Performance Division, only moderate progress was made in this work unit during the period of this report.

FOR REVIEW

(028)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD DR&E(AR)636	
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8A. DISSEM INSTRN	8B. SPECIFIC DATA- CONTRACTOR ACCESS	9. LEVEL OF SUM A. WORK UNIT
81 10 01	D. CHANGE	U	U	DA OG 8668	82 09 30	<input type="checkbox"/> YES <input type="checkbox"/> NO	
10. NO./CODES*	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
a. PRIMARY	61101A	3A161101A91C		00		028	
b. CONTRIBUTING							
c. CONTRIBUTING							
11. TITLE (Precede with Security Classification Code)* (U)Neuroanatomical Connections between the Nucleus Accumbens and the Preoptic and Anterior Hypothalamic Thermoregulatory Centers (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 005900 Environmental Biology; 003500 Clinical Medicine; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
81 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING		.7	
b. NUMBER:*				FISCAL		82	
c. TYPE:				YEAR		83	
d. KIND OF AWARD:				CURRENT		.7	
e. CUM. AMT.						11	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME:*				NAME:*			
USA RSCH INST OF ENV MED				USA RSCH INST OF ENV MED			
ADDRESS:*				ADDRESS:*			
NATICK, MA 01760				NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
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TELEPHONE: 256-4811				TELEPHONE: 256-4867			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: HAMLET, MURRAY P., D.V.M.			
				NAME: POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Preoptic and Anterior Hypothalamus; (U)Nucleus Accumbens; Horseradish Peroxidase; (U)Central Neural Temperature Regulation							
23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) The preoptic and anterior region of the hypothalamus is regarded as the center of thermal regulation. But the afferent and efferent projections of neurons to this area have not been determined by the horseradish peroxidase technique. The specific objective of this study is to determine the location of cells of origin and their efferent pathways which project between the preoptic and anterior hypothalamus thermoregulatory centers and the four divisions of the nucleus accumbens. It appears that the physiological significance of this neural pathway is in raising body temperature. Consequently excitation of this pathway may assist in the prevention and therapy of hypothermia and conversely inhibition of this pathway may extend the tolerance to hot environments. Thus, this neural pathway may affect the survival and performance of soldiers under a variety of ambient conditions.</p> <p>24. (U) The horseradish peroxidase technique will be used to study neuronal connections within the central nervous system. Horseradish peroxidase is taken up by nerve fibers at the site of injection and transported retrogradely in axons to the perikarya of origin. It can also be transported orthogradely. Thus, horseradish peroxidase neurohistochemistry enables the determination of the location of cells or origin and their afferent projection to the injection site, as well as the termination of efferent projections of cells at the injection site. Horseradish peroxidase will be injected into the preoptic and anterior hypothalamic thermoregulatory center and the different parts of the nucleus accumbens.</p> <p>25. (U) 81 10 - 82 09 Equipment and supplies have been obtained to start this project. In preliminary experiments, horseradish peroxidase was microinjected stereotaxically into the nucleus accumbens of anesthetized cats. Methodological difficulties in sectioning and staining of brain tissue are presently being resolved.</p>							

\*Available to contractors upon originator's approval.

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1 MAR 68PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65  
AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 028 Neuroanatomical Connections between the Nucleus Accumbens and the Preoptic and Anterior Hypothalamic Thermoregulatory Centers

Study Title: Neuroanatomical Connections between the Nucleus Accumbens and the Preoptic and Anterior Hypothalamic Thermoregulatory Centers

Investigators: Friedrich W. Klutzow, LTC, MC, M.D. and Carl A. Ohata, CPT, MSC, Ph.D.

Background:

The preoptic and anterior region of the hypothalamus is regarded as the center of temperature regulation. Neural structures in the limbic system appear to be important in the regulation of homeostasis. Thus, the functions of the hypothalamus appear to be duplicated by the limbic system. The underlying mechanisms of these functions are poorly understood since there may be multiple connections among these structures. The nucleus accumbens, a mesolimbic structure, appears to be important in raising body temperature. The hyperthermia due to amphetamines is attenuated by lesioning the nucleus accumbens (Wirtshafter et al., 1978). It is presumed that this hyperthermia is mediated by the activation of dopaminergic neurons originating in the nucleus accumbens which project to preoptic neurons responsible for raising body temperature. Neurons in the preoptic and anterior hypothalamic region respond to local temperature, neurotransmitters and modulators to elicit appropriate thermal responses (Bligh, 1966). All previous work on hypothalamic neural thermoregulation have been restricted to only the hypothalamus without examining other central neural inputs. There is an external trigger (i.e., reference input to the hypothalamic temperature set-point) in the hypothetical model of thermal control system advocated by Hammel (1968). But no anatomical connections or physiological mechanism has been demonstrated to support that theory. The specific objective of this study is to determine the location of cells of origin and their efferent projections between the nucleus

accumbens and the preoptic and anterior hypothalamus. Activation of this pathway may assist in the prevention and therapy of hypothermia and, conversely, inhibition of this pathway may extend the tolerance to hot environments. Thus, this pathway may affect the survival and performance of soldiers under a variety of ambient conditions.

#### Progress:

The horseradish peroxidase technique, which was refined by Mesulam (1978), is being used to determine the neuronal connections between the nucleus accumbens and preoptic and anterior hypothalamus. Horseradish peroxidase is taken up by nerve fibers at the site of injection and transported retrogradely to the perikarya of origin. It can also be transported orthogradely. Thus, horseradish peroxidase neurohistochemistry enables the determination of the location of cells of origin and their afferent projection to the injection site, as well as the termination of efferent projection of cells originating at the injection site.

In preliminary experiments, a microsyringe was stereotaxically positioned into the nucleus accumbens of anesthetized cats and horseradish peroxidase (10 mg in 0.5 microliters) was slowly injected over 30 minutes. After 24 hours survival time to allow for the uptake and transport of horseradish peroxidase, the cat was perfused with Karnovsky fixative then the brain was removed and stored in a sucrose cryoprotective solution. There are present difficulties in obtaining good 40 micron thick frozen coronal sections with a sliding microtome. The sections will be incubated in a solution containing hydrogen peroxide and chromogen. At sites containing horseradish peroxidase activity, the oxidized chromogen will produce a blue or brown colored reaction-product. The sites of staining will be determined with light microscopy after the sections are mounted on slides. Technical difficulties are presently being resolved. Dr. Henk Groenewegen, MIT Department of Neuroanatomy, was instrumental in initially assisting us but he has returned to the Netherlands. Dr. Marek-Marsel Mesulam, Harvard Neurological Unit, originally perfected the horseradish peroxidase technique and is presently assisting us.

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4. Wirthschafter, D., K.E. Asin and E.W. Kent. Nucleus accumbens lesions reduce amphetamine but not hyperactivity. *Eur. J. Pharmac.* 51:449-452, 1978.

FOR REVIEW

(001)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>		2. DATE OF SUMMARY <sup>a</sup>		REPORT CONTROL SYMBOL DD DR&E:AR 1636	
3. DATE PREV SUMRY 82 04 30	4. KIND OF SUMMARY D.CHANGE	5. SUMMARY SCTY <sup>a</sup> U	6. WORK SECURITY <sup>a</sup> U	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N NL	8B. SPECIFIC DATA CONTRACTOR ACCESS <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO		9. LEVEL OF SUM A. WORK UNIT	
10. NO./CODES: <sup>a</sup>		PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY		61102A		3M161102BS10		CA		001	
B. CONTRIBUTING									
C. <del>CONTRIBUTING</del>		STOG 80-7.2.4							
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Development and Characterization of Models of Cold Injury and Hypothermia (22)									
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 002300 Biochemistry; 005900 Environmental Biology; 012900 Physiology; 003500 Clinical Medicine									
13. START DATE 70 07			14. ESTIMATED COMPLETION DATE CONT			15. FUNDING AGENCY DA		16. PERFORMANCE METHOD C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS		B. FUNDS (in thousands)	
A. DATES/EFFECTIVE:				PRECEDING		82		3.0	
B. NUMBER: <sup>a</sup>				FISCAL		83		3.0	
C. TYPE:				CURRENT		83		102	
D. KIND OF AWARD:				E. CUM. AMT.					
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION					
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED					
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760					
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)					
NAME: IRONS ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> HAMLET, MURRAY P., D.V.M.					
TELEPHONE: 256-4811				TELEPHONE: 256-4865					
21. GENERAL USE				ASSOCIATE INVESTIGATORS					
Foreign Intelligence Not Considered				NAME: ROBERTS, DONALD E., Ph.D.					
				NAME: POC:DA					
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Frostbite; (U)Thermoregulation; (U)Hypothermia; (U)Laboratory Animal.									
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)									
23. (U) Study factors involved in frostbite and other non-freezing injuries in both animals and man. Provide a rational basis for treatment and prevention of those injuries sustained by military operations. Provide alternative methods of treatment and physiological considerations for alternatives.									
24. (U) A dog model (cooled to 25°C for 6 hours) is being used to study the physiological effects of hypothermia and in particular its effect on fluid shifts, electrolyte shifts, pH changes, and cardiovascular dynamics.									
25. (U) 81 10 - 82 09 Circulating fluid volumes (Evans Blue dye measurement), arterial blood pressure, heart rate, and cardiac output are significantly depressed during severe hypothermia (25°C). All return to near normal levels upon rewarming except cardiac output. Increases of venous return (saline infusion) during hypothermia (4 hrs. before rewarming) and before rewarming do not change the postresuscitation cardiac output (FASEB, 1982). Studies are continuing to determine the role of changes in cardiac contractility in this decrement and the extent of decreases of blood flow to other organ systems.									

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1 MAR 68PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE DD FORMS 1498A 1 NOV 65  
AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 001 Development and Characterization of Models of Cold  
Injury and Hypothermia  
Study Title: An Evaluation of Various Methods of Rewarming  
Hypothermic Victims  
Investigators: Donald E. Roberts, Ph.D., John Patton, Ph.D. and J. Grant  
Barr, CPT, MSC, Ph.D.

Background:

The recognition of accidental hypothermia as a medical problem both in the armed forces and the civilian sector has greatly increased. A successful rewarming is dependent on the ability to control physiological parameters as much as it is to supply heat. A variety of rewarming procedures have been shown to be successful in supplying heat. Correction of the alterations in blood chemistry, fluid balance, blood rheology, and acid-base balance produced by hypothermia is the real key to successful rewarming.

Progress:

This work unit is involved with determining certain physiological parameters during hypothermia and following these parameters, during treatment and rewarming procedures. The parameters under consideration include heart rate, cardiac contractility, cardiac output, arterial blood pressure, central venous pressure, core and surface temperatures, blood and urine electrolytes, blood gas tensions, and plasma volume.

The standard model is to cool the animal by external blanket at a rate of  $3^{\circ}\text{C}$  per hour until core temperature reaches  $25^{\circ}\text{C}$ . The animal is maintained at  $25^{\circ}\text{C}$  for six hours to simulate long term hypothermia. Measurements are taken before cooling, during cooling and after rewarming.

Severe hypothermia produces a metabolic icebox state in which cardiac output, heart rate, venous return, and energy requirements are significantly reduced. This slowed exchange causes an increase in  $\text{pCO}_2$  and pH and a decrease in  $\text{pO}_2$ . The decrease in body temperature results in an increase in

blood viscosity which further increases the problems of blood flow and gas exchange. This study is the outgrowth of trying to change the blood rheology by dilution during hypothermia and before rewarming.

The dogs were splenectomized and had a pressure transducer implanted in the left ventricle 2 weeks prior to the experiment. Mixed breed dogs ( $n=14$ ) were anesthetized with pentobarbital and catheters installed for arterial press, venous pressure and cardiac temperature. The dogs were cooled to a right atrial temperature of  $25^{\circ}\text{C}$  at a rate of  $3^{\circ}\text{C/hr}$ . The animals were maintained at  $25^{\circ}\text{C}$  for 6 hrs. and then rewarmed by external blanket at  $3^{\circ}\text{C/hr}$ . Seven animals were given normal saline (20% of plasma volume infused in 10 min.) four hours prior to rewarming.

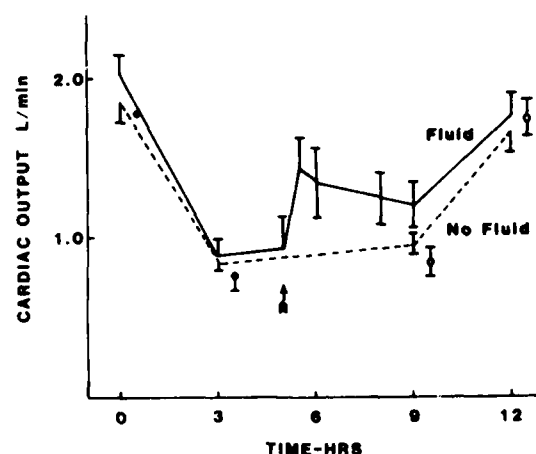


Figure 1. The time-course of cardiac output during hypothermia with and without fluid supplement.

Figure 1 shows the cardiac output (CO) over the total experiment. The dotted line is the CO of the group not receiving fluid and it is depressed and does not return to precooling levels after rewarming. The heart rate and blood pressure do return to normal or above normal while the hematocrit is elevated. Giving fluid at the arrow indicated in Figure 1 results in an increase in CO and this elevation is sustained for the next four hours. Following rewarming, the final level of CO is no different from those animals not receiving fluid although the level of CO before rewarming is different.

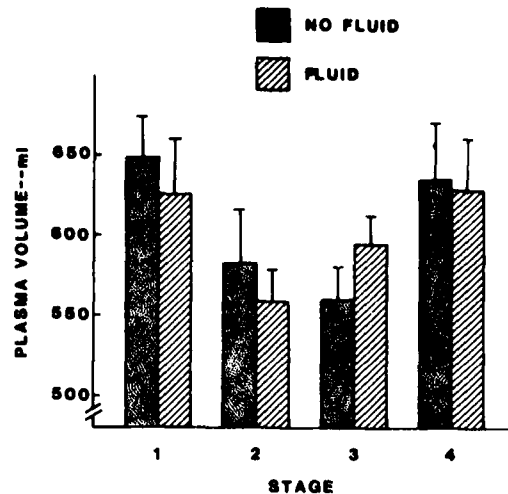


Figure 2. The relationship of plasma volume to hypothermia at 25°C for six hours and following rewarming.

Figure 2 indicates the plasma volume changes occurring during the experiment. Stage 1 is before cooling, stage 2 is at 25°C, stage 3 is at 25 after 6 hours, and stage 4 is after rewarming. Part of the saline given to the animals remains in the circulating fluid and can account for the higher CO prior to rewarming. Assuming that changes in blood viscosity are responsible for the decrease in CO, then fluid given prior to rewarming should increase cardiac output. The open circles in Figure 1 show the results of a third group of animals (n=6) in which saline was given just prior to rewarming. The results are the same with no additional increase in cardiac output upon rewarming.

Table 1 shows the experimental data concerning blood electrolytes and blood gases. The electrolytes are not indicative of dehydration and in the no fluid case, there is a gradual loss of potassium from the circulating volume. In many cases of humans in hypothermia, a high potassium is reported and is probably the result of dead cells. The blood gas data shows an anoxic animal, but not a dead animal. Giving fluid allows the animal to retain more potassium upon rewarming and is probably due to the dilution effect rather than increased urinary retention at the expense of sodium.

TABLE 1

Plasma electrolytes and blood gas data during severe hypothermia with and without fluid addition

	STAGE	NO FLUID		FLUID	
(Na <sup>+</sup> ) mEq/L	1	149.3	+ 1.0	149.4	+ 1.1
	2	147.5	+ 1.8	149.4	+ 1.0
	3	148.4	+ 1.3	149.6	+ 2.2
	4	147.2	+ 2.7	150.7	+ 2.6
(K <sup>+</sup> ) mEq/L	1	3.7	+ .1	3.8	+ .2
	2	3.5	+ .2	3.3	+ .1
	3	3.5	+ .2	3.4	+ .3
	4	3.3	+ .2	4.1	+ .2
pO <sub>2</sub>	1	70.7	+ 3.9	83.6	+ 4.2
	2	32.3	+ 3.2	30.2	+ 1.7
	3	38.1	+ 5.3	39.1	+ 5.8
	4	81.6	+ 4.0	90.0	+ 1.7
pCO <sub>2</sub>	1	49.1	+ 1.8	46.3	+ 1.0
	2	55.4	+ 2.9	63.1	+ 0.8
	3	62.5	+ 3.3	65.4	+ 5.2
	4	38.5	+ 3.5	38.5	+ 0.6
pH	1	7.162	+ .02	7.190	+ .03
	2	7.122	+ .03	7.010	+ .03
	3	7.066	+ .02	7.040	+ .04
	4	7.214	+ .01	7.180	+ .05

The conclusions of this study are that the apparent hypovolemia seen during hypothermia is not true dehydration and is self-restoring upon rewarming. Increasing the circulating fluid volume prior to rewarming does not result in returning the cardiac output to normal after rewarming.

Presentation:

Roberts, D.E., G. Barr, J. Patton, D. Kerr and R. Harris. Fluid replacement during hypothermia. Federation of American Society for Experimental Biology. New Orleans, April 1982. Fed. Proc. 41(5):1696, 1982.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1 AGENCY ACCESSION <sup>a</sup>		2 DATE OF SUMMARY <sup>a</sup>		REPORT CONTROL SYMBOL		
				DA OA 6144		82 09 30		DD DR&E/AR)636		
3. DATE PREV SUMMARY		4. KIND OF SUMMARY		5. SUMMARY SCTY <sup>a</sup>		6. WORK SECURITY <sup>a</sup>		7. REGRADING <sup>a</sup>		
81 10 01		D. CHANGE		U		U		NL		
8. NO./CODES: <sup>a</sup>		PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER		
A. PRIMARY		61102A		3M161102BS10		CA		002		
B. CONTRIBUTING										
C. COOPERATING		STOG 81-7.2.3								
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations										
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine										
13. START DATE			14. ESTIMATED COMPLETION DATE			15. FUNDING AGENCY		16. PERFORMANCE METHOD		
70 07			CONT			DA		C. IN-HOUSE		
17. CONTRACT/GRANT					18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS		B. FUNDS (In thousands)	
A. DATES/EFFECTIVE:					PRECEDING					
B. NUMBER: <sup>a</sup>					FISCAL YEAR		82		9.0	
C. TYPE:					CURRENT		83		9.0	
D. KIND OF AWARD:					F. CUM. AMT.				238	
19. RESPONSIBLE DOD ORGANIZATION					20. PERFORMING ORGANIZATION					
NAME: <sup>a</sup> USA RSCH INST OF ENV MED					NAME: <sup>a</sup> USA RSCH INST OF ENV MED					
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NAME: IRONS, ERNEST M. JR, COL, MSC					NAME: <sup>a</sup> MAHER, JOHN T., Ph.D.					
TELEPHONE: 256-4811					TELEPHONE: 256-4852					
21. GENERAL USE					SOCIAL SECURITY ACCOUNT NUMBER					
Foreign Intelligence Not Considered					ASSOCIATE INVESTIGATORS					
					NAME: BURSE, RICHARD L., Sc.D.					
					NAME: CYMERMAN, ALLEN, Ph.D. POC:DA					
22. KEYWORDS (Precede EACH with Security Classification Code) <sup>a</sup> (U)Laboratory Animals; (U)Acute Mountain Sickness; (U)Pulmonary Arterial Hypertension; (U)Hypoxic Tolerance; (U) Ventilatory Acclimatization										
23. (U) Acute mountain sickness and high altitude pulmonary edema are debilitating disorders associated with the lowered oxygen present at high terrestrial elevations. Many of the physiological and biochemical parameters of these disorders cannot be studied in man due to the invasive nature of the measurements. The purpose of this work unit is to develop appropriate animal models to enable: (a) the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations; and (b) the identification of new approaches for improving military effectiveness at high terrestrial elevations.										
24. (U) Models will be developed and/or used for investigating: (a) physiological and biochemical responses to altitude; (b) control mechanisms operative in these responses; (c) etiology and symptomatology of acute mountain sickness and high altitude pulmonary edema and; (d) related functional deficits and disabilities.										
25. (U) 81 10 - 82 09 (a) Precise measurement of arterial blood gas composition and acid-base status is essential in studies of respiration physiology, and requires exact corrections for variations in body temperature. Necessary correction factors for goat blood, an important animal model in studies of altitude acclimation, were established; (b) Altitude-exposed rats implanted with devices for the slow-release of fluoride had substantially higher fluoride levels in plasma, soft tissues, and bone than their sea-level counterparts, as well as severe disturbances in mineralization patterns of enamel and dentin; (c) Current understanding of lung physiology is incompatible with observations by others of higher CO <sub>2</sub> levels in expired air than in arterial blood. Our consistent findings of such 'reverse gradients' for CO <sub>2</sub> in goats during hyperoxic rebreathing add fuel to a controversy of fundamental importance; (d) Injection of atropine in low (0.5 mg/kg), moderate (1.0 mg/kg) and high (5.0 mg/kg) doses had no affect on the altitude tolerance of mice as measured by the exposure time required to induce hypoxic seizures.										

<sup>a</sup> Available to contractors upon originator's approval

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries and Health Hazards  
Work Unit: 002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations  
Study Title: The Mouse as an Animal Model to Test Pharmacologic Agents in Hypobaric Hypoxia  
Investigators: Russell J. Andrews, M.D., Paul B. Rock, CPT, MC, Ph.D., D.O., James A. Devine, SP5 Ian R. Johnson and John T. Maher, Ph.D.

Background:

The rationale, mouse model, small animal chamber, and experimental protocol for this study are summarized in the FY81 Progress Report (1) and are described in detail in the Study Research Plan (where extensive references are given)(2). Briefly, a Plexiglas and aluminum small animal chamber (36"X28"X20") was developed to maintain simulated altitudes of 35,000 feet (178 mmHg) or higher for 24 hours or more. The protocol consists of taking mice (Charles River CD-1 strain) to 35,000 feet over 25 minutes (1,400 ft/min), maintaining that altitude for one hour, then descending to sea level (760 mmHg) over approximately ten minutes.

Progress:

The Plexiglas and aluminum small animal chamber devised during FY81 was equipped with a discrete data acquisition control unit to permit automatic control of pressure, temperature, humidity,  $PO_2$ , and  $PCO_2$ . The protocol described above (ascent to 35,000 feet for one hour) was used with over 1,500 mice. Additionally, mice were maintained at a simulated altitude of 18,000 feet (380 mmHg) for four weeks (with return to sea level briefly once each week for food, water, weighing, and cleaning).

When mice were taken from sea level to 35,000 feet over 25 minutes, approximately 1/2 of control mice (injected with 0.5 cc of saline i.p.) underwent convulsions within the first 15 minutes at altitude. Rarely did a mouse which has seized survive the sixty minutes at 35,000 feet. The overall survival rate for the

control mice was 43%. To determine whether survival of one chamber run indicated enhanced survival for a second run, survivors (both experimental and control mice) were, at a later date, injected with 0.5 cc saline i.p. and again subjected to the altitude protocol. Their overall survival rate was 74% (Chi square for survival of first-run controls versus second-run mice (i.e. survivors):  $P \ll .001$ ).

Mice kept at a simulated altitude of 18,000 feet lost over five grams (more than 1/8 of total body weight) during the first week, with little change thereafter (see Table 1). Mean hematocrit increased over 20% in comparison with sea level controls. At the end of four weeks both groups underwent the protocol exposure to 35,000 feet. Survival among the sea level control mice was approximately 60%; among the acclimatized mice it was 17% (Chi square with Yates correction:  $P \sim .001$ ).

Drugs studied during FY82 using the mouse model were atropine and dexamethasone. Atropine was studied in three dose levels (.05, 1.0, and 5.0 mg/kg), the latter because of the heroic doses which may be employed in Mission Area V (Medical Defense Against Chemical Agents). Only when the highest dose (5.0 mg/kg) was given ten minutes prior to altitude exposure was there a clearly significant difference in survival between the experimental mice and the controls (Table 2).

Table 1

Weight, Hematocrit, and Survival Among Mice Subjected to Four Weeks at Sea Level versus 18,000 Feet Prior to Exposure to 35,000 Feet for One Hour

Group	N	Mean Weight (gm)					Mean Hct	Survival
		DA 1	DA 7	DA 14	DA 21	DA 28	DA 28	%
Sea Level A	24	38.1 **	-	-	-	37.3 **	45.5 *	58%
Sea Level B	24	34.7 **	-	-	-	34.0	48.2 ***	67%
18,000 Feet	23	38.0**	32.3	33.0	33.7	33.8	69.1	17%

Two sea level groups of differing weights were used to control for the loss in weight demonstrated by the mice exposed to 18,000 feet over the first week.

P values: \* < .005; \*\* < .001; \*\*\* < .0001

Chi square (with Yates correction) for survival of combined groups A & B versus the 18,000 feet group on exposure to 35,000 feet:  $P \sim .001$ .

The results for dexamethasone are also given in Table 2. Both the low and the high doses of dexamethasone, but especially the former, were detrimental when injected 16 hours prior to ascent; but not when injected at ten minutes or two hours prior. Since glucocorticoids have been found beneficial in treating certain types of cerebral edema (3), pulmonary hypertension (4), and nausea/vomiting (5), it was hoped a positive effect on altitude exposure would be found. The relatively common use of low dose steroids for various medical conditions makes clarification of this possible detrimental effect on humans at terrestrial elevations important. The effect may be related to the ability of glucocorticoids to decrease erythrophagocytosis, thereby raising hematocrit (6).

The following points can be made:

1. The significantly higher survival rate among the "re-run" mice (those surviving an initial protocol altitude exposure) indicates variability among mice in altitude tolerance. This is consistent with the predictive value found in human studies of ventilatory response to hypoxia for symptoms of acute mountain sickness when exposed to altitude (good ventilatory responders being relatively asymptomatic) (7).

2. Heroic doses of atropine administered at high terrestrial elevations can be expected to have a detrimental effect (on survival specifically, but no doubt on performance as well in non-fatal situations). Lesser doses of atropine would have a much less detrimental effect on survival, comparing favorably with non-atropinized individuals.

3. Dexamethasone has a relatively long detrimental effect (16 hours after administration) which is not evident when altitude exposure is more acute in relation to drug administration. This negative effect might be ameliorated by continuing to give dexamethasone periodically (every six or eight hours) to avoid a rebound phenomenon, although the hematocrit effect would be expected to worsen. Studies to define the detrimental effect at 16 hours will be conducted during FY83.

4. The other drugs outlined in the Research Plan (glycerol, dimethylsulfoxide, and phenytoin), as well as acetazolamide and respiratory stimulants such as doxapram and almitrine, are to be considered with the protocol during FY83.

5. Additional data will be gathered (e.g., regarding hematocrit) on experimental and control mice during prolonged exposure to simulated high

TABLE 2  
Mean Survival Times for Mice Injected with Atropine or Dexamethasone at Various Dosages  
and at Various Times Prior to Exposure to 35,000 Feet for One Hour

ATROPINE												
Group	Ten Minutes Prior			Two Hours Prior			Sixteen Hours Prior			P	N	P
	N	X	S.D.	N	X	S.D.	N	X	S.D.			
Control	62	45.25	26.01	62	58.19	27.98	48	54.12	27.73		48	
.05 mg/kg	62	46.62	25.90	62	50.94	28.38	48	53.68	28.97	.05 < P < .1	48	NS
Control	62	45.25	26.01	62	58.19	27.98	48	54.12	27.73		48	
1.0 mg/kg	62	44.80	26.05	62	55.36	28.27	48	59.44	28.00	NS	48	NS
Control	58	57.47	28.81	48	53.32	28.47	48	61.46	28.20		48	
5.0 mg/kg	58	44.69	27.45	48	54.32	27.30	48	54.41	28.44	NS	48	~ .1
DEXAMETHASONE												
Group	Ten Minutes Prior			Two Hours Prior			Sixteen Hours Prior			P	N	P
	N	X	S.D.	N	X	S.D.	N	X	S.D.			
Control	48	49.92	28.80	58	46.16	25.65	58	54.22	28.88		58	
.25 mg/kg	48	47.69	26.88	58	50.24	26.85	58	40.35	24.33	NS	58	< .005
Control	48	49.92	28.80	58	46.16	25.65	58	54.22	28.88		58	
5.0 mg/kg	48	49.60	29.11	57	46.39	28.56	58	46.22	26.40	NS	58	~ .05

X = mean survival time in minutes from beginning of ascent. Mice surviving the entire exposure are credited with 85 minutes (25 min. ascent plus 60 min. at 35,000 feet). For mice which seized and died, the survival time is the period from beginning of ascent to the midpoint between the first seizure and the last agonal gasp. Raters were blind as to experimental versus control groups.

S.D. = standard deviation.

altitudes during FY83, although the rapid adaptive response of the mouse to hypoxia makes such findings of more value to chronic studies in man at altitude than to the study of acute mountain sickness (8).

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 002 Development and Characterization of Models to Study  
Acute Mountain Sickness and High Altitude Pulmonary  
Edema in Military Operations  
Study Title: Effect of Adrenergic Blockers on Ventilatory  
Responsiveness in Goats  
Investigators: Steven Weinberger, M.D., Richard Harris, CPT, VC,  
Vladimir Fencel, M.D., Ronald Gabel, M.D. and Richard  
Steinbrook, M.D.

Background:

Ventilatory responses to a variety of physiologic stimuli, such as exercise, cannot be explained by alterations in arterial blood  $O_2$  and  $CO_2$  tensions. One factor that could modulate responsiveness to ventilatory stimuli is the level of adrenergic (i.e., sympathoadrenal) activity. That adrenergic activity can stimulate ventilation is suggested by studies demonstrating augmented minute ventilation after norepinephrine or isoproterenol administration (1,2). However, information is conflicting on the role of baseline sympathoadrenal activity in modifying ventilatory responsiveness. Acute administration of propranolol to normal subjects has been reported both to decrease (3) and to have no effect (4) on the ventilatory response to hypercapnia.

Since the sympathoadrenal system is responsible for many of the physiologic changes seen in response to acute stress, clarifying how this system interacts with ventilatory control is fundamental to understanding ventilatory responsiveness under stress and under various environmental conditions. We have been investigating this question by studying how adrenergic blocking agents affect ventilatory responses in goats.

Progress:

We have completed a study investigating the effect of alpha-adrenergic blockade (with phentolamine) and beta-adrenergic blockade (with propranolol) on the ventilatory response to hyperoxic  $CO_2$  rebreathing in awake goats. Five

goats were studied before and after administration of phentolamine (3.8 mg IV bolus followed by 0.19 mg/min) or propranolol (0.15 mg/kg IV).

Results of the  $\text{CO}_2$  response curves ( $\dot{V}_E$  vs  $P_{\text{ETCO}_2}$  and  $V_T/T_i$  vs  $P_{\text{ETCO}_2}$ ) before and after beta-blockade with propranolol are presented in Table 1. There was no statistically significant difference in mean values of the slopes, the X-intercepts, the minute ventilation ( $\dot{V}_E$ ) at  $P_{\text{ETCO}_2} = 70$  torr, or the mean inspiratory flow rate ( $V_T/T_i$ ) at  $P_{\text{ETCO}_2} = 70$  torr before vs. after propranolol for the 5 goats.

TABLE 1  
EFFECT OF BETA BLOCKADE ON  $\text{CO}_2$  RESPONSE CURVES IN AWAKE GOATS

	MINUTE VENTILATION ( $\dot{V}_E$ )		
	SLOPE ( $\text{L} \cdot \text{min}^{-1} \cdot \text{torr}^{-1}$ )	X-INTERCEPT (torr)	$\dot{V}_E$ AT $P_{\text{ETCO}_2} = 70$ TORR ( $\text{L} \cdot \text{min}^{-1}$ )
CONTROL	$1.77 \pm 0.35$	$54.3 \pm 2.0$	$25.9 \pm 3.1$
PROPRANOLOL	$1.55 \pm 0.29$	$54.1 \pm 2.1$	$23.0 \pm 3.4$
P	NS	NS	NS

	MEAN INSPIRATORY FLOW ( $V_T/T_i$ )		
	SLOPE ( $\text{L} \cdot \text{min}^{-1} \cdot \text{torr}$ )	X-INTERCEPT (torr)	$V_T/T_i$ AT $P_{\text{ETCO}_2} = 70$ TORR ( $\text{L} \cdot \text{min}^{-1}$ )
CONTROL	$3.84 \pm 0.84$	$52.7 \pm 2.0$	$60.6 \pm 7.2$
PROPRANOLOL	$3.48 \pm 0.72$	$53.1 \pm 2.1$	$54.0 \pm 7.2$
P	NS	NS	NS

Values are means  $\pm$  SE; n = 5.

Results of the  $\text{CO}_2$  response curves before and after alpha-blockade with phentolamine are presented in Table 2. There was no statistically significant change in mean values of the slopes, the X-intercepts, or  $\dot{V}_E$  calculated at  $P_{\text{ETCO}_2} = 70$  torr after phentolamine administration. When  $V_T/T_i$  was plotted against  $P_{\text{ETCO}_2}$ , there was a slight but statistically significant decrease in slope and X-intercept after phentolamine administration. However, there was no difference in  $V_T/T_i$  calculated from the regression line for  $P_{\text{ETCO}_2} = 70$  torr before compared to after phentolamine.

TABLE 2  
EFFECT OF ALPHA BLOCKADE ON CO<sub>2</sub> RESPONSE CURVES IN AWAKE GOATS

	MINUTE VENTILATION ( $\dot{V}_E$ )		
	SLOPE (L·min · torr <sup>-1</sup> )	X-INTERCEPT (torr)	$\dot{V}_E$ AT $P_{ETCO_2} = 70$ TORR (L·min <sup>-1</sup> )
CONTROL	1.95 ± 0.40	53.2 ± 2.6	29.6 ± 3.8
PHENTOLAMINE	1.85 ± 0.50	50.9 ± 3.3	29.9 ± 4.6
P	NS	NS	NS

	MEAN INSPIRATORY FLOW ( $V_T/T_i$ )		
	SLOPE (L·min <sup>-1</sup> · torr <sup>-1</sup> )	X-INTERCEPT (torr)	$V_T/T_i$ AT $P_{ETCO_2} = 70$ TORR (L·min <sup>-1</sup> )
CONTROL	4.26 ± 0.90	51.9 ± 3.2	68.8 ± 9.8
PHENTOLAMINE	3.78 ± 1.02	48.0 ± 3.9	70.1 ± 11.1
P	< 0.05	< 0.05	NS

Values are means ± SE; n = 5.

We conclude that acute administration of adrenergic blockers did not affect ventilatory response to CO<sub>2</sub> inhalation in goats, and suggest that adrenergic activity is not an important modulating influence for CO<sub>2</sub> responsiveness in this species.

The data from this study have been presented at the 1982 annual meeting of the Federation of American Societies for Experimental Biology (5). A manuscript describing this study is currently in preparation.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 002 Development and Characterization of Models to Study  
Acute Mountain Sickness and High Altitude Pulmonary  
Edema in Military Operations  
Study Title: Measurement of  $\beta$ -Endorphin Levels in Plasma and  
Cerebrospinal Fluid in Goats  
Investigators: Steven E. Weinberger, M.D., Richard Harris, CPT, VC,  
Vladimir Fencel, M.D., Ronald A. Gabel, M.D., Richard A.  
Steinbrook, M.D. and David E. Leith, M.D.

Background:

Recent studies have suggested that endogenous opioid peptides may be involved in ventilatory control in both animals and humans. In cats, Lawson et al. (1) demonstrated that phrenic nerve activity was increased after injection of the opiate antagonist, naloxone, suggesting that endogenous opioids may modulate central respiratory drive. In humans, Santiago et al. (2) suggested that endorphins may be responsible for the depressed response to resistive loads in some patients with chronic obstructive pulmonary disease, though Fleetham et al. (3) could not demonstrate a role for endogenous opioid peptides in ventilatory control in normal human subjects.

Most studies to date have utilized the opiate antagonist, naloxone, as the means for determining the importance of endogenous opioid peptides. Direct measurement of  $\beta$ -endorphin levels in plasma and cerebrospinal fluid has not yet been used to investigate a relationship between opioid peptide activity and ventilatory control. Since goats provide an excellent animal model for studying ventilatory control, we are interested in assessing the applicability of currently available radioimmunoassays for measurement of  $\beta$ -endorphin in plasma and cerebrospinal fluid samples obtained from goats.

Progress:

Plasma and cerebrospinal fluid were obtained from 6 goats for measurement of  $\beta$ -endorphin immunoreactivity and characterization of the

relative proportions of  $\beta$ -lipotropin and  $\beta$ -endorphin constituting the immunoreactivity. Since we were not interested in levels drawn from each goat, but rather in the usefulness of the radioimmunoassay technique, the samples were pooled to obtain sufficient material for study.

The radioimmunoassay was performed in the Endocrine Unit at Massachusetts General Hospital, according to a previously described technique (4). The antibody used for this assay was raised in rabbits against human  $\beta$ -endorphin, and the standard curve was obtained using camel  $\beta$ -endorphin. In this assay, the displacement curve for goat plasma was parallel to that obtained with camel endorphin, suggesting that there is excellent sequence homology between the immunoreactive sites of camel and goat  $\beta$ -endorphin. Analysis of individual plasma fractions after goat plasma was passed over a G-50 Sephadex column indicated that approximately 25% of the immunoreactivity was due to the presence of  $\beta$ -lipotropin, while approximately 75% was due to  $\beta$ -endorphin.

Beta-endorphin was also detected in cerebrospinal fluid of goats, though the measured level was lower than that found in plasma.

These preliminary studies will allow subsequent measurement of plasma and CSF endorphin levels in goats, and assessment of the effects of a variety of interventions, such as altitude exposure, on endorphin immunoreactivity.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 002 Development and Characterization of Models to Study  
Acute Mountain Sickness and High Altitude Pulmonary  
Edema in Military Operations  
Study Title: Development of a Plethysmograph for Measuring Pulmonary  
Ventilation in Unrestrained Rodents  
Investigators: Steven Weinberger, M.D., David E. Leith, M.D., Vincent A.  
Forte, Jr. and Richard A. Steinbrook, M.D.

Background:

Exposure of troops to high altitude results in changes in the control of breathing, derangements of acid-base balance in blood and cerebrospinal fluid, and associated decrements in physical and mental performance. One means of studying the physiologic mechanisms and trying to alter the clinical manifestations by drug treatment involves utilizing small animals, which can easily be exposed to hypobaric conditions.

Using small animals as models for studying human ventilatory acclimatization to altitude requires availability of a convenient and reliable technique for measuring ventilation in the experimental animals. The barometric method described by Drorbaugh and Fenn (1) allows measuring tidal volume and frequency of breathing in small animals confined to a closed box. With this technique, animals can be studied in the unrestrained and unanesthetized state without orotracheal intubation or tracheostomy. This method depends upon the pressure change in a tight box that results when an animal inspires air saturated with water at the temperature of the box. When taken into the lungs, the air is both warmed to body temperature and humidified to saturation at its new temperature. The combination of warming and humidification produces an increase in box pressure during inspiration, which returns to the starting pressure as the gas is exhaled.

This plethysmographic technique has now been used by several investigators for measuring tidal volume and frequency in small animals, and the utility of this method for studying rats as a model for human acclimatization to chronic hypoxia has been well demonstrated by Olson and Dempsey (2).

A recent adaptation of this method, described by Jacky (3), employs a reference chamber, and pressure changes in the animal chamber are measured relative to those in the reference chamber. This second chamber eliminates most of the pressure fluctuations due to changes in environmental conditions, and also allows rapid passage of different gas mixtures through both chambers without disturbing measurements in the animal chamber.

#### Progress:

In our initial studies, ventilatory responses were determined in rats during a ramp of increasing inspired  $P_{CO_2}$  (non-steady state), and during steady-state hypercapnia at different levels of hypoxia. Further preliminary studies revealed that inspired gas composition was more easily standardized, and ventilatory responses were more consistent, with steady-state than with ramp functions.

In Table 1 are preliminary data from four rats during steady-state hypoxia ( $PIO_2$  approximately 75 torr,  $PICO_2$  less than 4 torr), during air breathing, and during steady-state hypercapnia ( $PICO_2$  52-55 torr,  $PIO_2$  approximately 150 torr). Each mean value represents analysis of between 150 and 250 breaths. Each rat increased both tidal volume and respiratory frequency during hypoxia and during hypercapnia, as compared to breathing air. These data are in agreement with observations of Bartlett and Tenney (4) under similar conditions.

Having mastered the technique of measuring pulmonary ventilation during hypoxia, we are now beginning to study the effects of drugs on ventilatory acclimatization to high altitude. The first drug we are studying is naloxone, an opiate-receptor antagonist. Opiate drugs (e.g., morphine) are well-known ventilatory depressants, an effect readily reversed by naloxone. Endorphins are naturally-occurring polypeptides with opiate-like effects that are found in the brain and elsewhere and are reversed by naloxone. Endorphins may be involved with ventilatory responses to hypoxia. We are currently studying ventilatory responses during hypoxia and hypercapnia of rats given different doses of naloxone or placebo.

TABLE 1  
Ventilatory Responses in Rats During Hypoxia and Hypercapnia  
(Means  $\pm$  S.D.)

Rat	Air Breathing		Hypoxia ( $\text{PIO}_2 \approx 75$ torr)		Hypercapnia ( $\text{PICO}_2 \approx 54$ torr)	
	$\text{VT}$ (cc)	$\bar{f}$ ( $\text{min}^{-1}$ )	$\text{VT}$ (cc)	$\bar{f}$ ( $\text{min}^{-1}$ )	$\text{VT}$ (cc)	$\bar{f}$ ( $\text{min}^{-1}$ )
1	$2.54 \pm 0.63$	$114 \pm 21$	$3.50 \pm 0.94$	$146 \pm 11$	$4.82 \pm 0.74$	$152 \pm 5$
2	$2.91 \pm 0.49$	$94 \pm 16$	$3.95 \pm 0.82$	$118 \pm 15$	$4.69 \pm 0.45$	$138 \pm 6$
3	$2.79 \pm 0.28$	$85 \pm 11$	$3.67 \pm 0.57$	$141 \pm 9$	$5.14 \pm 0.80$	$147 \pm 6$
4	$3.05 \pm 0.47$	$80 \pm 34$	$3.05 \pm 0.16$	$133 \pm 13$	$3.84 \pm 0.62$	$136 \pm 10$

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Program Element: 6.11.02. A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 002 Development and Characterization of Models to Study  
Acute Mountain Sickness and High Altitude Pulmonary  
Edema in Military Operations  
Study Title: Fluoride Metabolism at Altitude  
Investigators: Gary M. Whitford, Ph.D., D.M.D., James A. Devine, John T.  
Maher, Ph.D., Nancy B. Allison and Birgit Angmar-Mansson,  
Ph.D., D.M.D.

Background:

Fluoride is a prototype bone-seeker. Its inclusion in bone mineral may improve the quality of the skeleton rendering it less susceptible to resorption, fracture and metabolic bone disease, notably osteoporosis (1). Fluoride is also given in large daily doses of from 20 to 60 mg as a part of the treatment regimen for osteoporosis (2). At relatively low levels of intake, such as with drinking water containing fluoride at 1 ppm, the ion typically inhibits the development of dental caries to the extent of 50 to 60 percent (3). All of these effects are related to local fluoride concentrations in or around the sites of action. Thus, factors that can influence the fractional retention, or balance, of ingested fluoride may affect the qualities of the dentition and skeleton of the soldier and members of his family.

The kidneys represent the major route for the removal of fluoride from the body. On average, about 50% of the fluoride ingested daily by adults is excreted in the urine during the following 24 hours although this fraction varies widely. Recent evidence indicates that the renal clearance rate of fluoride is directly related to urinary pH (4,5).

Persons subjected to hypobaric hypoxia, such as occurs at high altitudes, develop an incompletely compensated respiratory alkalosis. This condition is accompanied by an increase in the excretion of urinary bicarbonate and an elevation of urinary pH. This fact, together with the pH-dependency of the renal clearance of fluoride, suggested that animals living at high altitude might exhibit a relatively negative fluoride balance compared to animals living at sea level. This expectation formed the rationale for the current study.

### Progress:

Fourteen weanling rats were raised with a low-fluoride diet and distilled water until they reached a body weight of approximately 175 grams. Under ether anesthesia and via a 1 cm midline abdominal incision, a slow-release fluoride device was implanted intraperitoneally. Each device was predetermined to deliver fluoride at 1.1 mg/day.

Two groups of seven rats each were then housed in separate environmentally-controlled chambers for six weeks. One chamber was kept at 760 mmHg (sea level) and the other at 380 mmHg (5490 meters) with two 30-minute recompressions each week for cleaning and feeding. Throughout the six-week period, the animals had free access to low-fluoride food and distilled water.

At the end of the study, plasma and selected tissues were taken for analysis using the fluoride ion-specific electrode following diffusion and concentration with the acid-HMDS technique (6). The incisors of all rats were removed for photography and microradiographic analysis. For the latter analysis, planoparallel midsagittal sections, 60-80 microns thick, were prepared by manual grinding. Contact microradiography of the ground sections was performed with Ni-filtered Cu K $\alpha$  -radiation (1.54 A) at 18 kV with a focal spot-to-film distance of 750 mm. The microradiographs were studied and photographed in a Leitz photomicroscope.

It was apparent upon visual examination that the incisor enamel of the altitude rats was severely disturbed. It was white (normal rat enamel has a yellow-brown color), fractured or totally missing, with the underlying dentin exposed, at multiple sites. The enamel of the control or sea level rats appeared normal. The microradiographs of the enamel from the altitude rats revealed extreme disturbances in the mineralization patterns. They also indicated abnormal dentin formation patterns, viz., the presence of numerous, large lacunae. Based on these findings, microradiographic analyses of femurs are in progress.

The table shows the results of the fluoride and other analyses. The plasma, heart, liver and femur epiphysis fluoride levels were all higher in the hypobaric hypoxic group. Compared to the sea-level group values, these concentrations were higher by 55, 43, 61 and 59%, respectively. The heart water-to-plasma and the liver water-to-plasma fluoride concentration ratios were reduced in the

experimental group compared to the control group. These findings were consistent with the hypothesis that the distribution of fluoride between extracellular fluid and soft tissues is a function of the magnitude of the transmembrane pH gradient across cell membranes. The elevated femur fluoride levels of the altitude group reflected those of plasma. The phosphorus and ash contents of the bones were not different with statistical significance between the groups.

TABLE

<u>Variable</u>	<u>Group</u>	
	<u>Control</u>	<u>Altitude</u>
Plasma F , $\mu\text{M}$	6.6 $\pm .52$	10.7 $\pm 1.34$
Heart F , $\mu\text{M}^*$	5.1 $\pm .28$	7.3 $\pm .72$
Liver F , $\mu\text{M}^*$	6.1 $\pm .63$	9.8 $\pm 1.76$
Heart/Plasma	.780 $\pm .030$	.699 $\pm .031$
Liver/Plasma	.950 $\pm .108$	.895 $\pm .056$
Femur Distal Epiphysis F ppm**	710 $\pm 40$	1131 $\pm 66$
Femur Distal Epiphysis P , gm%**	10.41 $\pm .11$	10.62 $\pm .23$
Femur Distal Epiphysis F / P , %	1.11 $\pm .06$	1.76 $\pm .15$
Femur Distal Epiphysis, % Ash	60.8 $\pm .4$	59.7 $\pm .4$

Data expressed as Mean  $\pm$  SEM, n=7.

\*In terms of tissue water. \*\*In terms of dry weight.

As was discussed earlier, it was predicted that the tissues of the rats at altitude would contain less fluoride than those of the rats at sea level because of a less positive fluoride balance. The results indicated exactly the opposite. This does not necessarily mean that the pH-dependency of the renal clearance of fluoride was inoperative in this study. The results could be explained by other undetected changes such as reductions in glomerular filtration rate among the rats experiencing hypobaric hypoxia.

Additional studies are required to: 1) confirm the above findings; 2) include additional control groups, i.e., groups at sea level and at altitude without exposure to fluoride (to determine if the enamel and dentin changes at altitude were due to fluoride or to hypobaric hypoxia per se); 3) to quantitate urine and blood pH and  $\text{PCO}_2$ ; and 4) to discover the mechanism(s) of the increased fluoride balance associated with hypobaric hypoxia.

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6. Whitford, G.M., and K.E. Reynolds. Plasma and developing enamel fluoride concentrations during chronic acid-base disturbances. *J. Dent. Res.* 58: 2058, 1979.

FOR REVIEW

(005)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E/ARJ636	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8. DISSEM INSTR <sup>a</sup>	9a. SPECIFIC DATA CONTRACTOR ACCESS	9. LEVEL OF SUM A. WORK UNIT
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10. NO. CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	61102A	3M161102BS10		00		005	
B. CONTRIBUTING							
C. CO- <del>XXXXXX</del>	STOG 80-7.2:4						
11. TITLE (Precede with Security Classification Code) <sup>a</sup>							
(U) Models of Heat Disabilities: Preventive Measures (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup>							
016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
76 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:		EXPIRATION:		PRECEDING		9.0	
B. NUMBER:				FISCAL		333	
C. TYPE:		D. AMOUNT:		CURRENT		9.0	
E. KIND OF AWARD:		F. CUM. AMT.		83		375	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL <sup>a</sup>				PRINCIPAL INVESTIGATOR <sup>a</sup> (Furnish SSN of U.S. Academy Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> MAGER, MILTON, Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4871			
21. GENERAL USE				ASSOCIATE INVESTIGATOR <sup>a</sup>			
Foreign Intelligence Not Considered				NAME: FRANCESCONI, RALPH P., Ph.D.			
				NAME: HUBBARD, ROGER, Ph.D. POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code)							
(U)Heat Stress; (U)Heat Disabilities; (U)Volunteers; (U)Lab Animals; (U)Body Temperature; (U)Tolerance; (U)Heat							
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23.(U) The identification and investigation of measures designed to prevent or reduce the disabilities, injuries or performance decrements associated with military operations in the heat. Additionally, the study of factors which predispose military personnel to heat injury.</p> <p>24.(U) A variety of preventive measures, e.g., prehydration, dietary supplementation and pharmacological agents will be evaluated for their efficacy in protecting from heat injury. Models will be used to elucidate the role of obesity, dehydration, alcohol, drugs, nutritional deprivation, etc. in predisposing to heat illness.</p> <p>25.(U) 81 10 - 82 09. To determine the effects of low dosage organophosphate administration on exercise in a hot environment, malathion was administered IP to rats. The dosage (7.5 mg/day, 4 days) effected a 35% reduction in plasma cholinesterase levels; despite this inhibition, endurance was unaffected. While rates of heat gain were similar between groups, malathion treated rats displayed higher skin temperatures at several sampling times during the run. Exercise to hyperthermic exhaustion elicited increments in circulating levels of lactate, LDH, potassium, free nitrogen and creatinine, but these elevations were not exacerbated by malathion. In a separate study, rats were placed on a low sodium diet to quantitate the effects of hyponatremia on exercise in the heat. While rates of weight gain were severely depressed in the low sodium group, endurance capacity was unaffected. Rats given low sodium diets also displayed reduced heat loss with significantly lower skin temperatures although fluid consumption was identical between groups. In continuing studies of human adaptational responses to acute heat stress and exercise in the heat, we have demonstrated that cortisol was unaffected by plasma volume expansion and exercise in the heat. While aldosterone levels were reduced by plasma volume expansion, circulating levels of this hormone were increased during exercise in the heat; growth hormone levels were also increased during exercise in the heat. No correlations could be drawn between the intensity of these adaptational responses and the ability to complete the exercise protocol.</p>							

DD FORM 1498

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. ALL FORMS 1498A, 1498B, 1498C, 1498D, 1498E, 1498F, 1498G, 1498H, 1498I, 1498J, 1498K, 1498L, 1498M, 1498N, 1498O, 1498P, 1498Q, 1498R, 1498S, 1498T, 1498U, 1498V, 1498W, 1498X, 1498Y, 1498Z, 1498AA, 1498AB, 1498AC, 1498AD, 1498AE, 1498AF, 1498AG, 1498AH, 1498AI, 1498AJ, 1498AK, 1498AL, 1498AM, 1498AN, 1498AO, 1498AP, 1498AQ, 1498AR, 1498AS, 1498AT, 1498AU, 1498AV, 1498AW, 1498AX, 1498AY, 1498AZ, 1498BA, 1498BB, 1498BC, 1498BD, 1498BE, 1498BF, 1498BG, 1498BH, 1498BI, 1498BJ, 1498BK, 1498BL, 1498BM, 1498BN, 1498BO, 1498BP, 1498BQ, 1498BR, 1498BS, 1498BT, 1498BU, 1498BV, 1498BW, 1498BX, 1498BY, 1498BZ, 1498CA, 1498CB, 1498CC, 1498CD, 1498CE, 1498CF, 1498CG, 1498CH, 1498CI, 1498CJ, 1498CK, 1498CL, 1498CM, 1498CN, 1498CO, 1498CP, 1498CQ, 1498CR, 1498CS, 1498CT, 1498CU, 1498CV, 1498CW, 1498CX, 1498CY, 1498CZ, 1498DA, 1498DB, 1498DC, 1498DD, 1498DE, 1498DF, 1498DG, 1498DH, 1498DI, 1498DJ, 1498DK, 1498DL, 1498DM, 1498DN, 1498DO, 1498DP, 1498DQ, 1498DR, 1498DS, 1498DT, 1498DU, 1498DV, 1498DW, 1498DX, 1498DY, 1498DZ, 1498EA, 1498EB, 1498EC, 1498ED, 1498EE, 1498EF, 1498EG, 1498EH, 1498EI, 1498EJ, 1498EK, 1498EL, 1498EM, 1498EN, 1498EO, 1498EP, 1498EQ, 1498ER, 1498ES, 1498ET, 1498EU, 1498EV, 1498EW, 1498EX, 1498EY, 1498EZ, 1498FA, 1498FB, 1498FC, 1498FD, 1498FE, 1498FF, 1498FG, 1498FH, 1498FI, 1498FJ, 1498FK, 1498FL, 1498FM, 1498FN, 1498FO, 1498FP, 1498FQ, 1498FR, 1498FS, 1498FT, 1498FU, 1498FV, 1498FW, 1498FX, 1498FY, 1498FZ, 1498GA, 1498GB, 1498GC, 1498GD, 1498GE, 1498GF, 1498GG, 1498GH, 1498GI, 1498GJ, 1498GK, 1498GL, 1498GM, 1498GN, 1498GO, 1498GP, 1498GQ, 1498GR, 1498GS, 1498GT, 1498GU, 1498GV, 1498GW, 1498GX, 1498GY, 1498GZ, 1498HA, 1498HB, 1498HC, 1498HD, 1498HE, 1498HF, 1498HG, 1498HH, 1498HI, 1498HJ, 1498HK, 1498HL, 1498HM, 1498HN, 1498HO, 1498HP, 1498HQ, 1498HR, 1498HS, 1498HT, 1498HU, 1498HV, 1498HW, 1498HX, 1498HY, 1498HZ, 1498IA, 1498IB, 1498IC, 1498ID, 1498IE, 1498IF, 1498IG, 1498IH, 1498II, 1498IJ, 1498IK, 1498IL, 1498IM, 1498IN, 1498IO, 1498IP, 1498IQ, 1498IR, 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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCE, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 005 Models of Heat Disabilities: Preventive Measures  
Study Title: Low Sodium Diet: Effects on the Ability to Work in the  
Heat.  
Investigators: Ralph Francesconi, Ph.D., Roger Hubbard, Ph.D. and Milton  
Mager, Ph.D.

Background:

Recently, Hubbard et al. (1) have documented and quantitated the physical, physiological, and thermoregulatory decrements induced by prolonged feeding to rats of a diet deficient in potassium content. While hyponatremia, or deficient sodium levels, has long (2) been identified as a factor in the etiology of heat illness, the quantitative effects of reduced sodium levels on the physiological and thermoregulatory responses during work in the heat have not been documented. In fact, in their recent review on heat illnesses, Shibolet et al. (3) question the importance of sodium reserves in heat injury and unequivocally state that there seems to be no need for salt supplementation in the acclimatized subject. The present study was undertaken to investigate and document thoroughly the effects of a low sodium diet on the ability to work in the heat.

Progress:

To this end, immature (approx. 150g) male rats were placed on a specially formulated low-sodium diet (US Biochemical Corporation, Cleveland, Cat. No. 21675), and remained on this diet until experimentation. Control rats were placed on a semi-purified diet (USBC, Cat. No. 10662) fortified with a mineral mix containing sodium chloride. Both groups were fitted with indwelling Silastic catheters (external jugular vein) for blood sampling. At experimentation, all rats exercised on a level treadmill (9.14 m/min) in the heat (35°C) until hyperthermic exhaustion ( $T_{re} = 43^{\circ}\text{C}$ ) occurred. Blood samples were taken immediately prior to and following exercise in the heat to hyperthermic exhaustion.

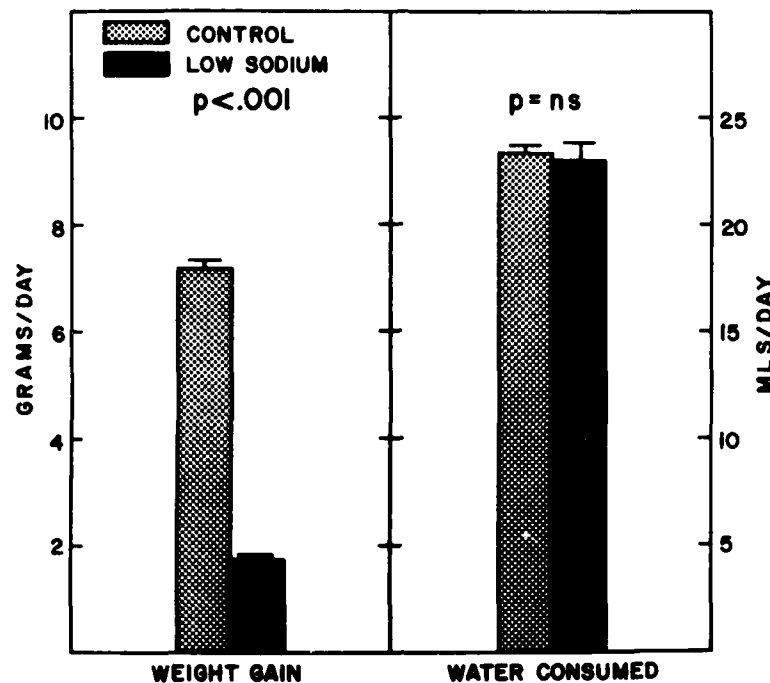


Figure 1. Effects of a low sodium diet on growth rate and water consumption of rats.

Figure 1 demonstrates a significant ( $p < .001$ ) decrement in the rate of body weight gain among animals on the low sodium diet. Thus, these rats required nearly 60 days to achieve their running weight of  $234.9 \pm 1.9$  g (mean  $\pm$  S.E.). Controls were carefully weight matched, and had a mean weight of  $236.31 \pm 1.7$  g ( $p > .05$ ) at the time of the run. It is interesting to note that despite the huge differences in rates of weight gain, both groups of rats consumed virtually identical ( $p > .05$ ) water volumes on a daily basis. Figure 2 demonstrates that despite the nutritional deprivation, endurance capacities were similar ( $p > .05$ ) between groups. Weight lost during the run was significantly ( $p < .05$ , one-tailed T test) greater among control rats thus indicating larger fluid availability for thermoregulation.

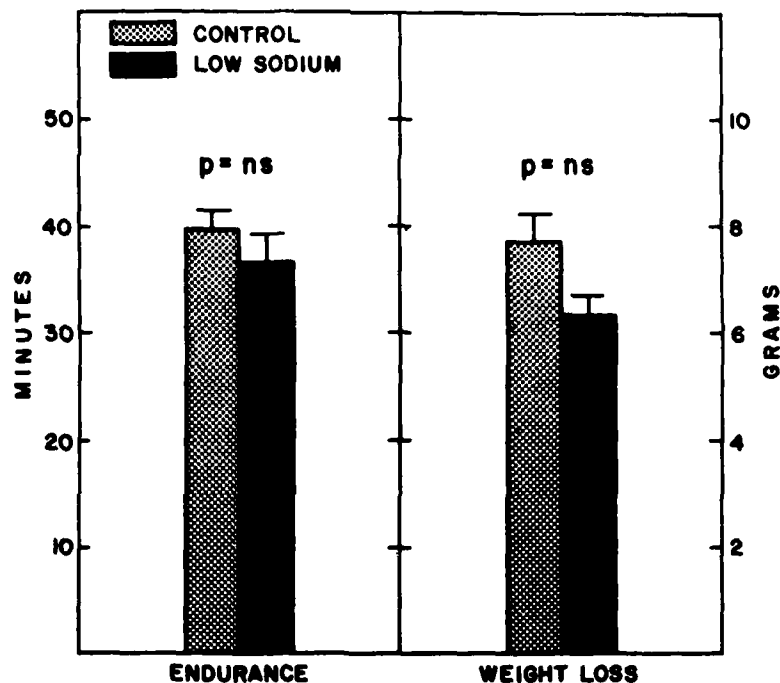


Figure 2. Effects of a low sodium diet on endurance and weight loss during exercise in the heat to hyperthermic exhaustion.

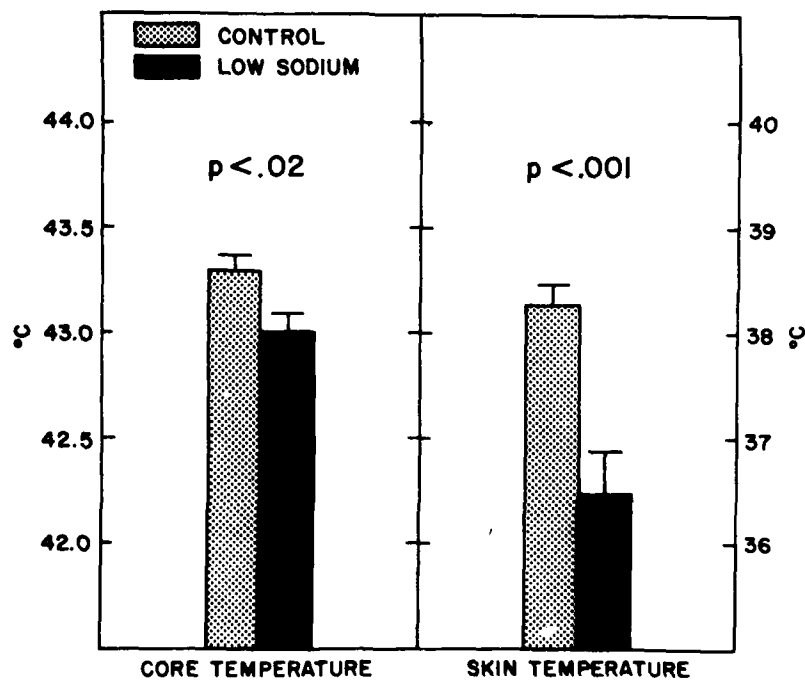


Figure 3. Effects of a low sodium diet on final core and skin temperatures following exercise in the heat to hyperthermic exhaustion.

Figure 3 illustrates that while final core temperatures were identical ( $p > .05$ ) between groups, the low-sodium group demonstrated a reduced ability to dissipate heat to the environment manifested in significantly ( $p < .001$ ) lower final skin temperatures. The reason for this decremented peripheral blood flow may be noted in the significantly ( $p < .001$ ) increased hematocrit ratios both before and after exercise in the heat to hyperthermic exhaustion in the sodium deprived animals.

Thus, the results of this experiment demonstrated that despite severe effects on growth rate, heat dissipation, and hematocrit ratio, rats chronically fed a low-sodium diet apparently suffered no ill effects with respect to physical performance (endurance capacity). On-going analysis of the blood samples will specify the effects of a low sodium diet on the clinical chemical indices of heat/exercise injury.

#### Presentation:

Francesconi, R. and M. Mager. Heat exposure and exercise effects on plasma levels of renin, aldosterone, and vasopressin. *Physiologist*. 24:13, 1981.

#### Publication:

Mager, M. and R. Francesconi. The relationship of glucose metabolism to hypothermia. *Proc. Conf. on Nature and Treatment of Hypothermia*. U. Minnesota Press, Minneapolis, 1982. (In press).

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3. Shibolet, S., M.C. Lancaster, and Y. Danon. Heatstroke: a review. *Aviat. Space Environ. Med.* 47:280-301, 1976.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCE, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 005 Models of Heat Disabilities: Preventive Measures  
Study Title: Moderate Acetylcholinesterase Inhibition: Effects on the  
Ability to Work in the Heat  
Investigators: Ralph Francesconi, Ph.D., Roger Hubbard, Ph.D. and  
Milton Mager, Ph.D

Background:

The toxicological and physiological effects of organophosphate poisoning are generally attributed to acetylcholinesterase inhibition at cholinergic synaptic sites (1). The anti-cholinergic drug, atropine, and the acetylcholinesterase reactivator, pralidoxime chloride, are the most widely used antidotes (2) to organophosphate poisoning. However, both these therapeutic agents possess a variety of side effects (3); of particular interest to us is the well-documented interference of atropine with heat-loss mechanisms (3). In conjunction with a systematic investigation of the effects of atropine on thermoregulation and exercise in the heat, it is also necessary to quantitate the effects of agent simulators alone on these parameters.

Progress:

Adult, male rats (300 - 350 g) were treated with the widely used insecticide, malathion, (7.5 mg/day, 4 days) to induce moderate inhibition of circulating (plasma) cholinesterase levels. Experimental and control rats (injected with medium alone) had been previously fitted with indwelling Silastic catheters (external jugular vein) for rapid and convenient blood sampling. The final dosage of malathion was injected 25-30 min prior to withdrawal of 1.0 ml blood for the assay of cholinesterase levels as well as the clinical chemical indices (pre-run) of heat/exercise injury. A similar volume of blood sample had been removed before the first injection of malathion to establish control levels of both plasma cholinesterase activity and the clinical indices of heat/exercise injury. All rats exercised on a level treadmill (9.14 m/min) in the heat (35°C) until hyperthermic exhaustion ( $T_{re} = 43.0^{\circ}\text{C}$ ) was attained. Immediately upon completion of the exercise bout, a second (post-run) blood sample was taken.

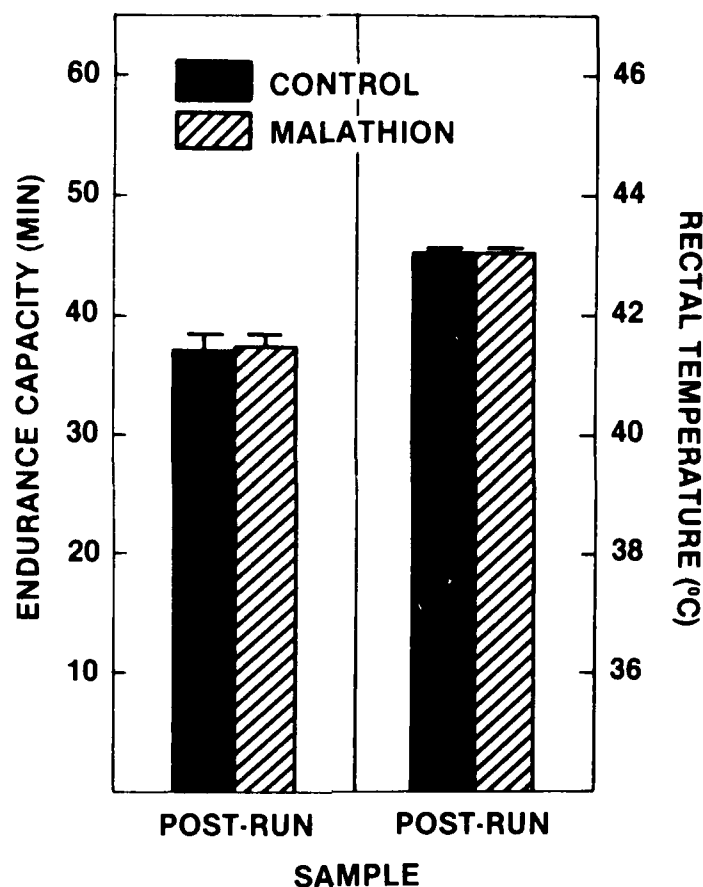


Figure 1. Effects of malathion administration on endurance and final rectal temperature after exercise in the heat to hyperthermic exhaustion.

Figure 1 (left) demonstrates that the administration of malathion had no effects on the endurance of rats exercising in the heat. Treadmill times for both groups ( $n = 12$ ) were virtually identical as were the final rectal temperatures achieved at exhaustion immediately upon termination of the treadmill run ( $p > .05$ ). Rectal ( $T_{re}$ ) and skin ( $T_{sk}$ ) temperature responses are depicted in Figure 2. Results indicate that no significant differences in  $T_{re}$  occurred at any of the sampling times. The slight divergence in  $T_{re}$  occurring at the end of the run is due to the fact that a number of rats have dropped out after 37 min in both groups. It is noteworthy that  $T_{sk}$  of the malathion treated rats is significantly ( $p < .05$ ) elevated at a number (e.g. 7-12, 14-23 min) of sampling times. However, the physiological significance of this effect is minor since  $T_{re}$  are essentially identical during these intervals.

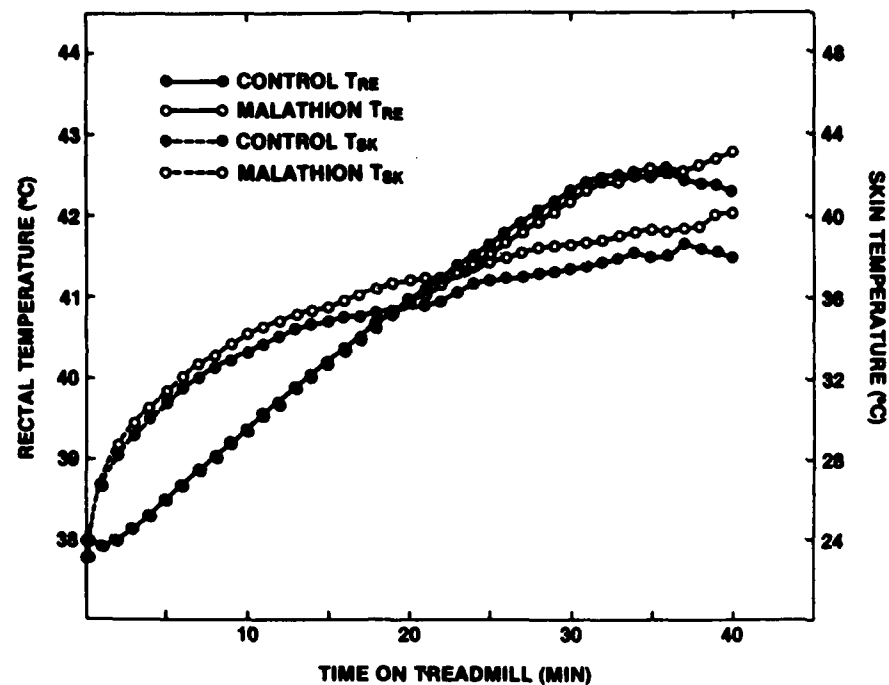


Figure 2. Effects of malathion administration on rectal and skin temperature responses during exercise in the heat to hyperthermic exhaustion.

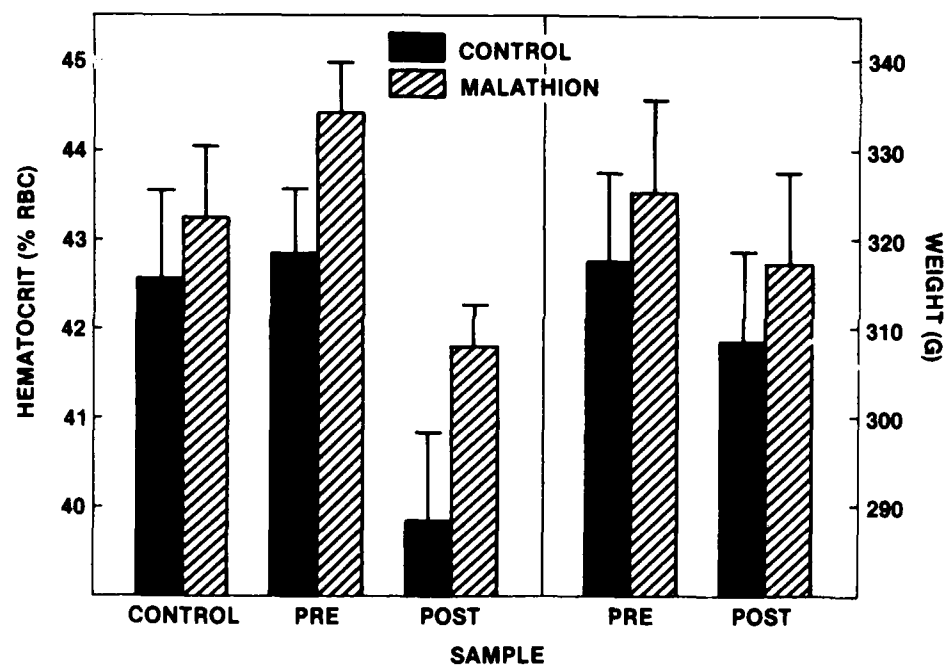


Figure 3. Effects of malathion administration on hematocrit ratios and body weights prior to and during exercise in the heat to hyperthermic exhaustion.

Figure 3 (left) demonstrates that malathion administration had no ( $p > .05$ ) effects on hematocrit ratios. However, during exercise in the heat there did occur a significant decrement in both groups, probably indicative of an influx of water into the vascular space ( $p < .01$ ). It is also evident that malathion had no effects ( $p > .05$ ) on body weights before experimentation, and likewise had no effects on the significant ( $p < .001$ ) weight losses occurring during exercise in the heat in both groups. This loss of weight during exercise represents primarily salivary and evaporative water loss for thermoregulatory benefit.

Malathion administration in adult rats (30 mg, total dose) effected a 35.3% ( $p < .01$ ) inhibition of cholinesterase activity, but had no effect on circulating levels of lactate or glucose before and after exercise in the heat to hyperthermic exhaustion. However, exercise in the heat to hyperthermic exhaustion resulted in significant ( $p < .01$ ) elevations of plasma lactate in both groups. Malathion administration had no effects on plasma levels of creatine phosphokinase, lactate dehydrogenase, potassium, sodium, creatinine, and urea nitrogen. However, exercise in the heat to hyperthermic exhaustion resulted in increased levels of LDH, potassium, urea nitrogen and creatinine.

#### Publication:

Francesconi, R., R. Hubbard, and M. Mager. Thermoregulatory responses in the rat to exercise in the heat following prolonged heat exposure. *J. Appl. Physiol.: Respirat. Environ. Exercise Physiol.* 52:734-738, 1982.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCE, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 005 Models of Heat Disabilities: Preventive Measures  
Study Title: Albumin-Induced Plasma Volume Expansion and Exercise in  
the Heat: Effects on Hormonal Responses in Men  
Investigators: Ralph Francesconi, Ph.D., Michael Sawka, Ph.D., Roger  
Hubbard, Ph.D. and Milton Mager, Ph.D.

Background:

Exposure of humans to acute heat stress (1) or exercise protocols (2) ordinarily results in significant increments in circulating levels of the fluid regulatory hormones, such as aldosterone, vasopressin, and angiotensin I. Increments in levels of these regulatory hormones may be related to the maintenance or increase of fluid volume during exposure to environmental heat or exercise. Stress hormones, such as cortisol (3) and growth hormone (4) respond similarly to environmental and exercise stress.

Acclimatization to heat in humans is characterized by an increased ability to work in the heat subsequent to greater cardiovascular and thermoregulatory efficiency, which has been partially attributed to plasma volume expansion. Senay (5) demonstrated that this expansion of plasma volume could be explained by an influx of interstitial protein and water into the circulatory system. In an earlier study (6) we had demonstrated in humans that one hour after the infusion of hyperoncotic albumin solution, there occurred a significant increase in plasma volume which persisted for approximately 12 hrs. The purpose of the present investigation was to determine whether plasma volume expansion could modulate the anticipated hormonal responses pursuant to the combined stresses of heat and exercise.

Procedures:

Seven adult, unacclimatized male test volunteers (Ss) participated in this study; they entered the heat chamber (45°C, 20% RH), and following removal of a blood sample, received an infusion of either human albumin (50 g/200 ml) or saline alone (200 ml). They then remained seated for an additional 60 min, and a

second resting blood sample was removed. Ss were then asked to stand for 30 min after which a third blood sample was taken, and this was followed by an exercise bout (1.56 m/s, treadmill, grade that elicited 40%  $\dot{V}C_2$  max) designed to last for 90 min. Further blood samples were obtained at 15 min intervals, and analyzed for the hormones under investigation.

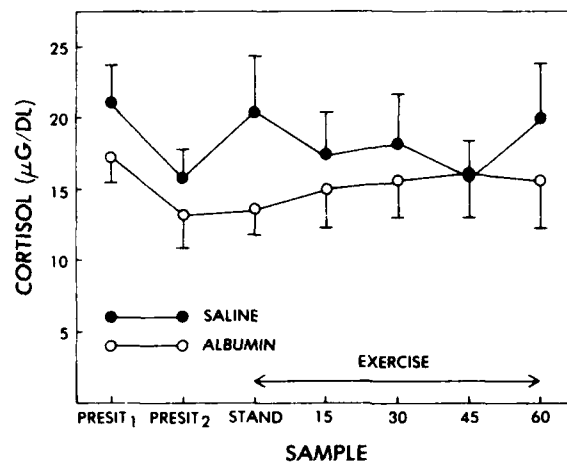


Figure 1. Effects of plasma volume expansion and exercise in the heat on plasma levels of cortisol.

Figure 1 demonstrates that there were no significant ( $p > .05$ ) effects of either albumin administration or exercise in the heat on levels of plasma cortisol. It might be noted that during the time course of this experiment normal diurnal decrements in levels of cortisol would ordinarily have occurred, but the exercise in the heat evidently prevented this decrease in both groups. Figure 2 demonstrates that in both groups there occurred statistically significant ( $p < .05$ ) increments in levels of growth hormone during exercise in the heat.

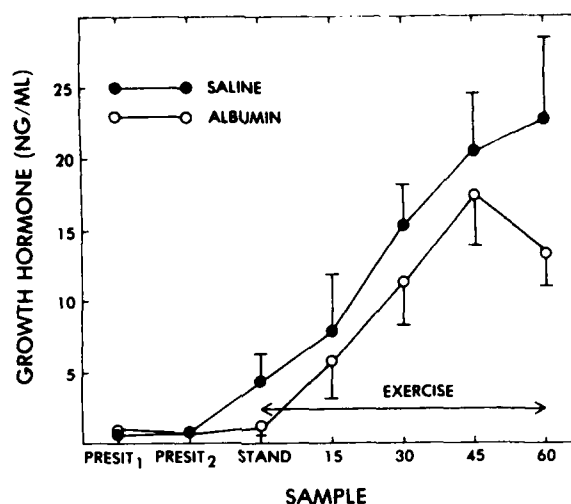


Figure 2. Effects of plasma volume expansion and exercise in the heat on plasma levels of growth hormone.

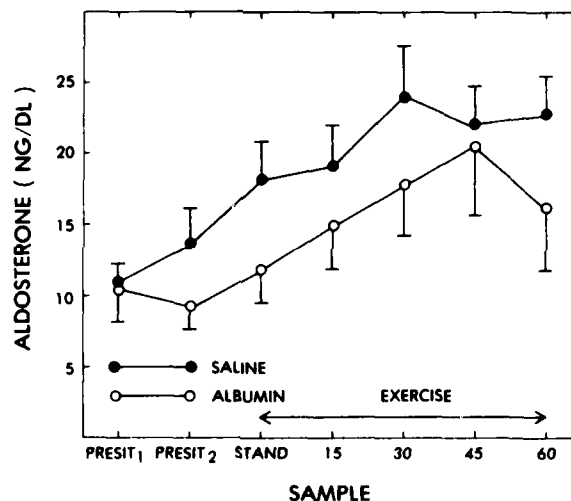


Figure 3. Effects of plasma volume expansion and exercise in the heat on plasma levels of aldosterone.

Figure 3 illustrates the effects of postural changes on levels of aldosterone since in both trials (saline, 30 min vs sit 1; albumin 45 min vs sit 2; both  $p < .05$ ), significant effects of exercise are negated when comparisons are made with the respective standing samples rather than with samples taken while sitting. Levels of angiotensin I were not initially affected by albumin administration. However, the increment occurring after postural change was more pronounced during the saline trial leading to significant intertrial differences ( $p < .05$ ) in the stand, 15 min, and 30 min samples.

We have concluded that exercise in the heat can affect the normally occurring circadian reduction in plasma cortisol which occurs during the morning hours. While aldosterone was affected by posture and exercise, growth hormone was significantly increased by exercise in the heat in both trials. The increased plasma volume appeared to have a significant effect on angiotensin I levels, but these were unaffected by mild exercise. Generally, however, plasma volume expansion had relatively minor effects on stress hormones as well as fluid regulatory hormones.

Presentation:

Francesconi, R. and M. Mager. Hypo- and hyperglycemia in rats: effects on the ability to work in the heat. Federation of American Society for Experimental Biology. New Orleans, April 1982. Fed. Proc. 41:1753, 1982.

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6. Hubbard, R.W., W.T. Matthew, D. Horstman, R. Francesconi, M. Mager and M. Sawka. Effects of IV albumin administration on plasma volume expansion in the heat. Fed. Proc. 41:1348, 1982.

FOR REVIEW

(009)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY					1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E(AR)636	
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISSEM INSTR <sup>a</sup>	8B. SPECIFIC DATA- CONTRACTOR ACCESS	9. LEVEL OF SUM A. WORK UNIT	
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10. NO./CODES: <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER		
A. PRIMARY	61102A	3M161102BS10		CA		009		
B. CONTRIBUTING								
C. <del>CONTRIBUTING</del>	STOG 80-7.2:4							
11. TITLE (Precede with Security Classification Code) <sup>a</sup>								
(U)Biological Processes that Limit Heavy Physical Work Ability of the Soldier (22)								
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup>								
012900 Physiology								
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD		
76 10		CONT		DA		C. IN-HOUSE		
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS		B. FUNDS (In thousands)
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B. NUMBER: <sup>a</sup>				FISCAL YEAR				
C. TYPE:				CURRENT				
D. KIND OF AWARD:								
E. AMOUNT:								
F. CUM. AMT.								
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION				
NAME: <sup>a</sup>				NAME: <sup>a</sup>				
USA RSCH INST OF ENV MED				USA RSCH INST OF ENV MED				
ADDRESS: <sup>a</sup>				ADDRESS: <sup>a</sup>				
NATICK, MA 01760				NATICK, MA 01760				
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)				
NAME: IRONS, ERNEST M. JR., COL, MC				NAME: <sup>a</sup> VOGEL, JAMES A., Ph.D.				
TELEPHONE: 256-4811				TELEPHONE: 256-4800				
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER				
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS				
				NAME: PATTON, JOHN F., Ph.D.				
				NAME: KNUTTGEN, HOWARD K., Ph.D. POC:DA				
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Exercise Capacity; (U)Anaerobic Power; (U)Fatigue; (U)Military Performance; (U)Muscle Fibers; (U)Ergometry								
23. TECHNICAL OBJECTIVE. <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)								
<p>23. (U) The combat soldier often depends upon his ability to perform sustained and sometimes severe levels of muscular exertion. The objectives of this research are to: (a) identify and characterize those biological processes that influence his capacity to perform heavy work, thereby providing a rational basis for improving the soldier's performance; and (b) identify the physiological and biochemical processes that occur during physical training both at the whole body and muscle level, thereby providing a rational basis for improving physical training programs.</p> <p>24. (U) Specific areas of study will include: (a) environmental influences on physiological work capacity and performance; (b) affects of disease or other altered states of the body on exercise performance capacity, (c) development of measures and methods of training for anaerobic fitness, and (4) relationship of muscle histochemistry to muscular strength and endurance.</p> <p>25. (U) 80 10 - 81 09 (a) Investigations continue toward developing a laboratory measure of anaerobic power capacity. A very high intensity ergometer has been built for this purpose (up to 1500 watts) and calibration has been completed. Collection of performance curves (watts vs. exhaustion time) has been initiated. (b) A study has been completed to determine the recruitment patterns among different types of muscle fibers during high-intensity exercise with eccentric contractions. Results suggest that this type of exercise causes a preferential type I fiber recruitment and a significant reduction in glycogen utilization.</p>								

<sup>a</sup> Available to contractors upon originator's approvalDD FORM 1498  
1 MAR 68PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A: 1 NOV 65  
AND 1498-1: 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 009 Biological Processes that Limit Heavy Physical Work  
Ability of the Soldier  
Study Title: Effect of Panax Guingerefolium (American Ginseng) on  
Physiological Responses to and Recovery from Repeated  
Exhaustive Runs: Blood Assay Aspects  
Investigators: Joseph Knapik, SP6, M.S., James Wright, CPT, MSC, Ph.D.,  
Michael Welch, Ph.D., Paul Rock, CPT, MC, Ph.D., D.O.,  
John Patton, Ph.D. and Marilyn Teves, M.S.

Background:

Ginseng is an ergogenic aid that has been shown to increase time to exhaustion in a variety of physical tasks and to provide a more rapid recovery from physical exhaustion (1,2). Two possible mechanisms of action for these effects have been advanced in the literature. Avakian and Evonuk (3) found that rats administered ginseng and forced to swim for 1.5 or 3 h used less muscle glycogen in their distal quadriceps femoris (white muscle) than a group given a saline injection. Since no significant difference was noted in liver glycogen depletion between the two groups, Avakian and Evonuk suggested that increased lipid oxidation may have accounted for the glycogen sparing effect of ginseng.

Dardymov (4) has summarized some Russian work on ginseng that, while not dealing specifically with exercise, may provide some insight into the mechanism of action. With ginseng, the adrenal cortex of animals subjected to (undefined) stress did not enlarge. One study suggested that during stress cortiosteroids combine with B-lipoproteins (low density lipoproteins) in the blood and have the effect of reducing both hexokinase activity and the permeability of cell membranes for glucose. Independent experiments by Dardymov showed that B-lipoproteins inhibited hexokinase in vitro and caused disorders of the cell membrane in vivo. If ginseng was added, hexokinase was not inhibited.

These two hypotheses may seem contradictory, one arguing for increased fat oxidation and the other for increased glucose flux into the tissue and increased glucose phosphorylation. However, once glucose is phosphorylated, it

may be either converted to glycogen or to fructose - 6-phosphate. The former is not likely during exercise since there is a decrease in the active form of glycogen synthase (5). On the other hand, there is increased glycolytic flux during exercise (6) suggesting that any glucose entering the active muscle tissue would be ultimately converted to pyruvate. Increased lipid oxidation would decrease pyruvate oxidation by the inhibition of acetyl CO-A on pyruvate dehydrogenase (7). Pyruvates would be converted to lactate, alanine or malate (8). Thus, it may be possible to reconcile these hypotheses.

The purpose of the present study was to examine the influence of chronic ginseng administration on repeated exhaustive exercise. Another portion of this report details the cardiovascular and performance effects while this reports examines the serum substrate, enzyme, and hormonal data collected in an attempt to probe the mechanism of action of ginseng.

#### Progress:

From February to April 1982, 21 West Point Cadets who were also marathon runners were tested. The pretest was designed as follows. A resting blood sample was obtained from the subjects after an overnight fast. The evening after the resting, blood sample  $\dot{V}O_2$  max was determined on each subject using a discontinuous treadmill protocol. For three consecutive days after the  $\dot{V}O_2$  max determination, subjects exercised at 85% of  $\dot{V}O_2$  max on a treadmill to exhaustion. Blood samples were obtained from an indwelling venous catheter at rest (2-10 min before exercise) and during exercise at minutes 10, 20, 30 and every subsequent 30 min until exhaustion. Expired gas samples were taken at these same time intervals in order to calculate R-values.

After the pretest was completed, subjects were paired on the basis of their treadmill run times and assigned to either a ginseng or a placebo group. Both groups were given identical capsules and told to ingest one capsule per day. Four weeks later subjects were post-tested in a manner identical to the pretest. Five subjects in the ginseng group and six subjects in the placebo group completed all testing.

The resting blood samples were analyzed for glucose, total protein, albumin, globulin, calcium, phosphorus, cholesterol, triglycerides, urea nitrogen, uric acid, creatinine, bilirubin (total and direct), alkaline phosphatase, lactate dehydrogenase, SGOT, SGPT, sodium, potassium, chloride, iron, high density

lipoproteins and low density lipoproteins. The blood samples obtained during exercise were analyzed for glucose, lactate, free fatty acids, glycerol, CPK, LDH, insulin, cortisol and growth hormone.

All the above mentioned assays have been completed and the data placed in a computer file and verified. Some preliminary data analysis has been performed on the exercising blood samples. A 3-way ANOVA runs (6 treadmill runs to exhaustion) X time (5 sample times-rest, 10, 20 and 30 min of exercise, and post exercise) X group (ginseng or placebo) has been calculated on some of the blood parameters. No significant main effect of group or any interaction involving group was found to be significant in the following parameters: R values, insulin, cortisol, growth hormone, glucose, lactate, glycerol, FFA, CPK or LDH. Thus, preliminary analysis suggests chronic ginseng administration does not influence dream substrates, enzymes, or hormones under the conditions of this investigation.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
009 Biological Processes that Limit Heavy Physical Work  
Ability of the Soldier  
Study Title: Effects of Panax Guinguefolium (American Ginseng) on  
Physiological Responses to and Recovery from Repeated  
Exhaustive Runs  
Investigators: Marilyn Teves, M.S., James E. Wright, CPT, MSC, Ph.D.,  
John F. Patton, Ph.D., Michael Welch, Ph.D., USMA, Paul  
B. Rock, CPT, MC, Ph.D., D.O. and Joseph J. Knapik, M.S.

Background:

The projected battlefield of the future may consist of 8-13 days or more of intense combat, with a maximum of 4 hours rest/man/day. Fatigue—both mental and physical—presents a major obstacle to the successful completion of soldiering tasks in this type of scenario. Any substance which acts as an ergogenic aid, or adaptogen (a substance which facilitates the adaptation of the organism to stress) would be extremely valuable to our military readiness.

For centuries, the Chinese have reported that ginseng has adaptogenic qualities. There have been numerous citings of reductions in the adverse consequences of a variety of physical, biological and chemical stressors, and of increased physical work capacity in animals due to ginseng administration, as referenced by Brekhman and Dardymov (1). A recent study by Avakian and Evonuk (2) has demonstrated a glycogen sparing effect during prolonged exercise in rats treated with Panax Korean ginseng.

Progress:

In a double blind study, 18 male West Point Cadet marathoners were studied to determine the effects of 30 days of ginseng administration on their physiological responses and performance on repeated exhaustive runs on the treadmill (TM). Mean age, height, weight, percent body fat, and lean body mass of the two groups are shown in Table 1.

TABLE 1  
Physical Characteristics of the Subjects

Group	n	Age (Yr)	Height (cm)	Weight (kg)	Percent Body Fat	Lean Body Mass (kg)
Ginseng						
$\bar{X}$	6	20	173.8	69.8	10.6	62.4
SEM		0.6	2.8	2.8	0.8	2.4
Placebo						
$\bar{X}$	6	24	179.1	75.0	11.3	66.5
SEM		2.6	3.1	3.0	1.1	2.0

Ss performed an incremental TM  $\dot{V}O_2$  max test, then ran to exhaustion on the next three consecutive days at 8 mph with the TM grade adjusted to elicit  $84 \pm 1.0\%$   $\dot{V}O_2$  max ( $\bar{X} \pm \text{SEM}$ ). Ss were then divided into two groups of equal ability. Experimental Ss (G) consumed a daily dosage of 2 gm Korean ginseng with a chromatographically-assayed glycoside content of 1.5% (personal communication, Dr. A. deMarderosian, contract agent for ginseng supplies), while control Ss (C) received a dextrose placebo. At the end of four weeks, the  $\dot{V}O_2$  max test and three runs to exhaustion were repeated.

Pre-treatment measures of  $\dot{V}O_2$  max were  $65.5 \pm 1.2$  and  $63.5 \pm 1.5$  ml/kg/min ( $\bar{X} \pm \text{SEM}$ ) for the G and C groups, respectively. There were no significant differences between groups in heart rate or ventilatory measures recorded during the pre and post treatment  $\dot{V}O_2$  max tests.

Both groups demonstrated a significant decrease in run time to exhaustion (RT) from run 1 to run 3 during pre-and post-treatment measures, but there was no significant difference between groups. RT for all endurance runs are illustrated in Figure 1.

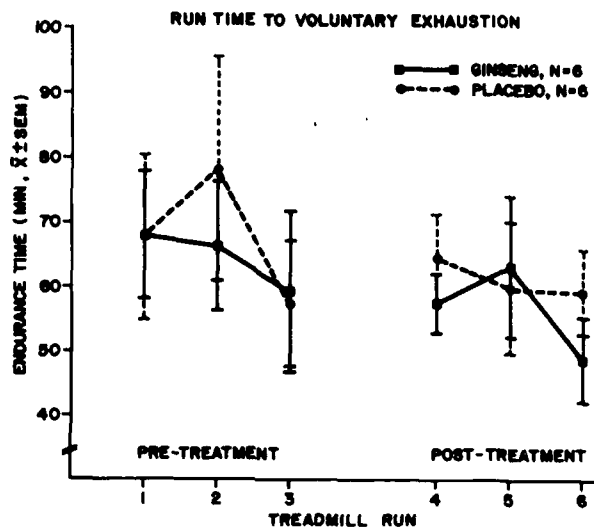


Figure 1. Run time to exhaustion, by group, on three consecutive days, before and after ginseng/placebo administration.

During the 6 runs to exhaustion, blood samples were collected pre-exercise, every 10 min for the first 30 min, and every 30 min thereafter, until the final sample at the point of exhaustion. As evidenced in Table 2, post-exercise blood lactate levels did not differ significantly following ginseng administration.

TABLE 2

Post Exercise Blood Lactate Levels Following  
Exhaustive Treadmill Runs

	Treadmill Run					
Group	1	2	3	4	5	6
Ginseng						
$\bar{X}$	5.35	5.34	5.01	4.67	5.78	4.74
SEM	0.89	1.06	0.70	0.88	1.23	1.19
N = 6						
Placebo						
$\bar{X}$	4.10	4.53	5.27	4.58	3.74	4.66
SEM	0.83	0.83	0.90	1.15	0.85	0.97
N = 6						

Ginseng is reported to be an adaptogen with glycogen sparing effects during prolonged exercise (3). Three consecutive days of running to exhaustion places a severe stress on the body's energy stores, therefore, any substantive glycogen sparing effect due to ginseng should theoretically have been demonstrated in a longer RT. This hypothesis was not confirmed, no doubt, partly because of the huge day to day variation in the RT measure. Based on these results, Korean ginseng, with a glycoside content of 1.5%, does not appear to reduce the stress of, or facilitate, recovery from running to exhaustion on three consecutive days, as measured by changes in RT to exhaustion or post exercise blood lactate levels.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 009 Biological Processes that Limit Heavy Physical Work  
Ability of the Soldier  
Study Title: Force and Power Development During Concentric and  
Eccentric Cycle Exercise  
Investigators: Howard G. Knuttgen, Ph.D., John F. Patton, Ph.D. and  
James A. Vogel, Ph.D.

Background:

Human performance of physical exercise is studied in the laboratory with the use of ergometers---devices employed to control and/or measure exercise intensity. One of the most popular ergometric devices has been and is the cycle ergometer used principally for leg exercise. While the physiological responses and adaptations of human subjects to cycle ergometer exercise have been extensively studied, relatively little attention has been given to the patterns of force development by the subject on the cycle pedals and the resultant power transfer between subject and ergometer. Additionally, those reports which have appeared in the literature have been confined to concentric contraction exercise and to either exercise intensities in the range which can be supported by predominantly aerobic metabolism (therefore, relatively long-term exercise periods lasting 30-120 minutes) or extremely high intensity and short-term periods (lasting some seconds).

A new cycle ergometer (Knuttgen et al., 1982 and USARIEM 1982 Progress Report, pp. 129-132) has been developed which can be employed for both concentric and eccentric contraction exercise and, further, can control and measure intensities ranging from within the limits of steady-state aerobic exercise through the highest intensities of which the subjects are capable. Therefore it is now possible to study the patterns of force development and power transfer in the widest possible range of exercise intensities both for concentric and eccentric contractions. (Note: Concentric contraction exercise is characterized as involving shortening contractions of the active musculature, movement closer together of the skeletal parts to which the muscles are attached, and transfer of power from subject to ergometer while eccentric

contraction exercise involves the active musculature being subjected to forced stretch, the bony attachments of the muscles being moved further apart, and power being transferred from the ergometer to the subject).

#### Progress:

More recently, the ergometer has been modified so as to provide information on the patterns of force transfer from the exercising subject. Strain gauges mounted on the pedal arms provide signals for continuous recording of both bending and elongation forces. At the same time, potentiometers permit simultaneous recording of the position of the pedal crank as well as the position of each pedal relative to its pedal arm (i.e., the pedal crank).

It will be the purpose of this study to determine the patterns of force transfer between human subjects and the pedal crank during a wide range of intensities of both concentric and eccentric exercise on a leg cycle ergometer. The controlled variables will be type of exercise (concentric or eccentric), intensity (power), and pedal crank rpm (therefore, velocity of muscle shortening and lengthening). This information will prove useful to the study of the relationship of the physiological capabilities of human subjects (including muscle fiber types) to force and power development under the conditions controlled by the ergometer. Subsequently, additional studies will relate these data to the phenomena of fatigue and the design of conditioning programs.

Approximately eight volunteer subjects will be recruited to perform bouts of exercise on the ergometer at a variety of power levels performed at different rpm for both concentric and eccentric contraction exercise. In addition to these bouts of exercise from which force patterns will be obtained, the following assessments of each subject will be performed to interpret better these results: aerobic power capacity ( $\dot{V}O_2\text{max}$ ), isometric and dynamic leg strength, anaerobic power capacity (Wingate test), and muscle biopsy of thigh musculature.

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Knuttgen, H.G., J.F. Patton and J.A. Vogel. An ergometer for concentric and eccentric muscular exercise. *J. Appl. Physiol.* 53(3):784-788, 1982.

Program Element: 6.11.02.A. DEFENSE RESEARCH SCIENCE, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 009 Biological Processes that Limit Heavy Physical Work  
Ability of the Soldier  
Study Title: Recruitment of Extrafusal Muscle Fibers during Exercise  
with Eccentric Contractions  
Investigators: Howard G. Knuttgen, Ph.D., William J. Evans, Ph.D. and  
John F. Patton, Ph.D.

Background:

Patterns of recruitment for skeletal muscle fibers (motor units) have been fairly extensively investigated for a variety of exercise conditions involving concentric and isometric muscle contractions (1,2,4). Virtually nothing is known about the patterns of fiber recruitment for exercise with eccentric contractions.

A person engages in a great amount of physical activity with eccentric muscle contractions during the course of each day. All effort in the work of lowering an object or the body, itself, depends on eccentric contractions. Each step in walking and running involves some eccentric contraction activity as the lead foot strikes the ground while walking downstairs is predominantly eccentric contraction exercise. Athletes are continuously employing eccentric contraction in preparation for the propulsive acts of jumping and throwing. Additionally, eccentric muscle contractions have been observed to be somewhat more effective in strength development than either concentric or isometric contractions (3). Such activity has been employed for years in the clinical setting for strength rehabilitation and the gymnasium for high-level strength development on the basis of empirical observations.

The purposes of this study, therefore, were to determine: 1) the recruitment patterns among the different types of extrafusal muscle fibers during high-intensity exercise with eccentric contractions and 2) the effects of training on both the recruitment patterns and the accompanying metabolic events.

### Progress:

Seven healthy volunteer subjects engaged in a three-phased study. Phase #1 involved a pre-training battery of tests involving leg-strength assessment, maximal aerobic power during concentric leg cycling, thigh muscle sampling (punch biopsy) to determine extrafusal fiber distribution and metabolic enzyme activities, and a test involving eccentric leg cycling at a high intensity. Phase #2 involved five weeks of exercising training (3 periods per week of 1 hour duration) at the same eccentric exercise intensity. Phase #3 consisted of a repetition of the testing protocol involved in Phase #1.

Glycogen use during exercise in the pre-training phase amounted to  $22.4 \pm 3.4$  mmol/kg wet weight and fell to  $13.0 \pm 2.3$  mmol/kg wet weight post-training, a reduction of 42% ( $p < .05$ ). In the pre-training period during 30 min of eccentric exercise,  $\dot{V}O_2$  ranged from 0.80 - 1.18 l/min during the first 4 min and then continued to demonstrate increases for the remainder of the exercise periods. The mean of the final values was 130% of the 2-4 min values. Heart rates at the end of exercise averaged 136 beats/min.

The training period resulted in a general decrease in  $\dot{V}O_2$  and heart rate throughout exercise. At 45 min of exercise,  $\dot{V}O_2$  was reduced by 32% from 1.41 l/min pre-training to 0.95 l/min post-training ( $p < .05$ ). Both before and after training, 30 min of eccentric exercise resulted in a significant glycogen depletion in Type I compared to Type II fibers. Muscle enzyme activities, however, did not change as a result of the training.

The data show, therefore, that high intensity eccentric training results in a reduction in  $\dot{V}O_2$  and glycogen utilization at the same absolute intensity. This adaptation may be a motor learning response since  $\dot{V}O_2$  max and muscle enzyme activities remained unchanged with training.

### Presentation:

Evans, W.J., J.F. Patton, E.C. Fisher and H.G. Knuttgen. Muscle metabolism during high intensity eccentric exercise. Fifth International Symposium on Biochemistry of Exercise. Boston, MA. 3, 1-4 June, 1982.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL	
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10. NO. CODES*	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER	WORK UNIT NUMBER		
a. PRIMARY	61102A	3M161102BS10		CA	010		
b. CONTRIBUTING							
c. CONTINUING	XXXXXX	STOG 80-7.24					
11. TITLE (Precede with Security Classification Code)* (U)Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 010100 Microbiology; 003500 Clinical Medicine; 005900 Environmental Biology; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
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17. CONTRACT GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:		EXPIRATION:		PRECEDING		8.0	
b. NUMBER:				FISCAL YEAR		232	
c. TYPE:		d. AMOUNT:		CURRENT		8.0	
e. KIND OF AWARD:		f. CUM. AMT.				229	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME:* USA RSCH INST OF ENV MED				NAME:* USA RSCH INST OF ENV MED			
ADDRESS:* NATICK, MA 01760				ADDRESS:* NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME:* BOWERS, Wilbert D., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4862			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: HAMLET, MURRAY P., D.V.M.			
				NAME: DuBOSE, DAVID A., M.S. POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Hyperthermia; (U)Heatstroke; (U)Tolerance; (U)Endotoxin; (U)Fibrinectin; (U)Hepatic Necrosis; (U)Therapeutic drugs; (U)Bile; (U)Pathology; (U)Laboratory Animal.							
23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) The objectives of these studies are to develop and utilize adequate subcellular, cellular, organ, and whole animal models to clarify the mechanisms of pathological changes produced by environmental extremes. Instability in areas of relatively hot climates necessitates planning for possible deployment of large numbers of troops to relatively hot environments. These studies apply disciplines of pathology to devise methods of prevention, prognosis and amelioration.</p> <p>24. (U) Carbon clearance will be used to determine the presence or absence of a stimulated reticuloendothelial system (RES). Such an evaluation may define a role for the RES in the pathophysiology of heat stress mortality. The isolated perfused liver has proven to be a useful tool for establishing time/temperature relationships for heat-induced hepatic injury. With this model system, the value of potential hepatoprotective agents in ameliorating heat-induced injury is under investigation.</p> <p>25. (U) 81 10 - 82 09 RES clearance function was significantly improved by sublethal heat exposure or by chemical stimulation with either endotoxin or zymosan. Both sublethal heat exposure and endotoxin treatment were associated with significant tolerance to lethal heat stress, while zymosan treatment was not. RES clearance function may serve as an indicator of the heat acclimatized state. The presence of insulin and hydrocortisone in the perfusates of livers perfused at 37°C, 41°C, 42°C and 43°C resulted in increased bile production at all temperatures, reduced K<sup>+</sup> leakage at all temperatures except 43°C, and reduced GPT and GOT leakage, only at 42°C. Histological and ultrastructural evaluations, and statistical analysis are in progress. This hormone containing perfusate will be utilized to compare the hepatoprotective effects of other membrane stabilizing substances in reducing heat injury.</p>							

\*Available to contractors upon originator's approval

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries and Health Hazards  
Work Unit: 010 Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes  
Study Title: Evaluation of the Capacity of Therapeutic Agents to Ameliorate Heat-Induced Liver Damage in the Isolated Perfused Liver  
Investigators: Wilbert D. Bowers, Jr., Ph.D., Roger W. Hubbard, Ph.D. and Murray P. Hamlet, D.V.M.

Background:

Previous studies with isolated perfused livers characterized heat-induced lesions, established time/temperature relationships, proposed a sequence of events leading to irreversible heat injury, and established baseline data for evaluating the effects of membrane stabilizers. Damage to cellular membranes and subsequent changes in permeability are typical heat-induced changes; therefore, glucocorticoids such as hydrocortisone may exert beneficial effects by stabilizing lysosomal membranes (2), reducing prostaglandin release (1), and/or maintaining normal capillary permeability. Since derangements in carbohydrate metabolism have also been reported in heatstroke (3) and hypoglycemia is not uncommon, infusion of insulin, which to a large extent regulates carbohydrate metabolism, may protect the heated liver by preventing net loss of glycogen. This report describes results obtained when these two drugs, hydrocortisone hemsuccinate (10.97 mg) and insulin (11.39 IU), were added to a complex perfusate prior to perfusion at 37°, 41°, 42° and 43°C. All livers were perfused for 90 min. and there were 9 livers per group. Bile production, K<sup>+</sup> leakage, alanine aminotransferase (GPT) and aspartate aminotransferase (GOT) leakage, light microscopic and electron microscopic structure were used as indicators of the degree of hepato-protection afforded by these drugs in the prevention or reduction of heat injury.

Progress:

The presence of insulin and hydrocortisone increased total bile production at all temperatures (Fig. 1), although the volume of bile was steadily reduced in both the treated and untreated with increasing temperature. Bile production was

linear in both treated and untreated groups at 37°C. However, the timing of cessation of bile production was delayed in the groups treated at 41°C and 42°C (Figs. 2 and 3).

Normal cells retain K<sup>+</sup> against a gradient through an energy requiring process. Elevations of K<sup>+</sup> in the perfusates reflect damage to this system. Changes in K<sup>+</sup> accumulations in the perfusates are indicated in figures 4, 5 and 6. Note that at the end of the 90 minute perfusions at 43°C (Fig. 4), K<sup>+</sup> levels in the treated and untreated groups were identical. This indicates that damage to this parameter was beyond the capacity of these drugs to protect with a 90 min. 43°C exposure; however, at 42°C and 41°C the treatment provided some benefit. Figures 5 and 6 show the changes in perfusate K<sup>+</sup> with time and temperature. The total amount of K<sup>+</sup> in perfusates after 90 min. at 43°C represents approximately 27% of the available intracellular K<sup>+</sup> in normal livers. Controls (37°C treated and 37°C untreated) either reduced perfusate K<sup>+</sup> levels or maintained the same level after a temporary reduction. Except for these groups, all groups released increasing quantities of K<sup>+</sup> after 30-45 min.

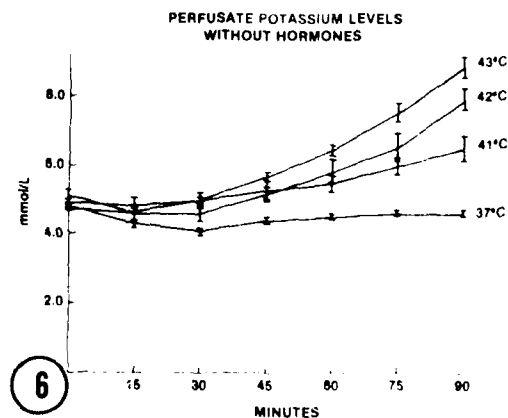
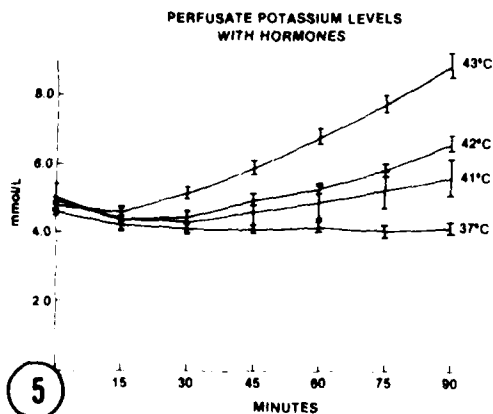
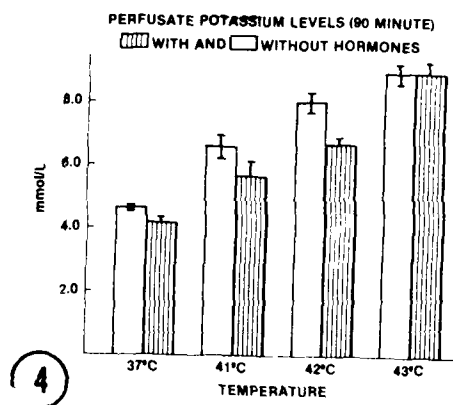
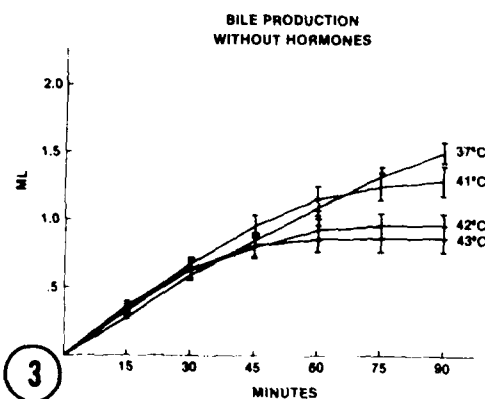
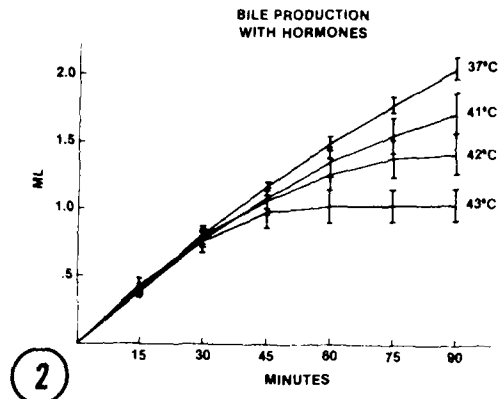
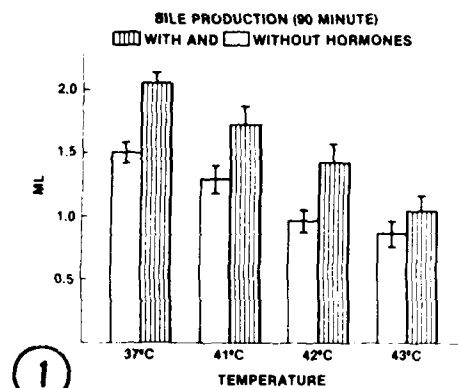
Bile production and K<sup>+</sup> retention represent metabolic functions of hepatocytes. When total bile production (Fig. 1) and final K<sup>+</sup> levels in the perfusates (Fig. 4) were compared, these showed a strong inverse relationship (.99) suggesting a similar sensitivity to heat. This was further supported by the timing of reduced bile production (after 30 min.) and increased perfusate K<sup>+</sup> (after 15-30 min.).

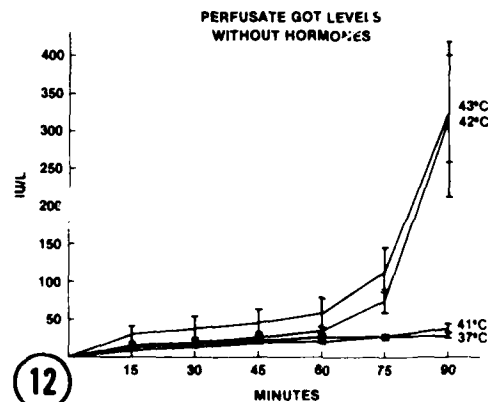
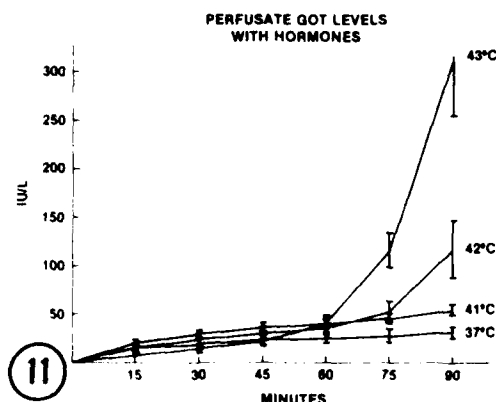
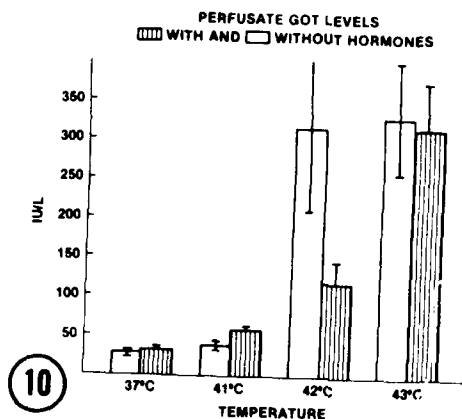
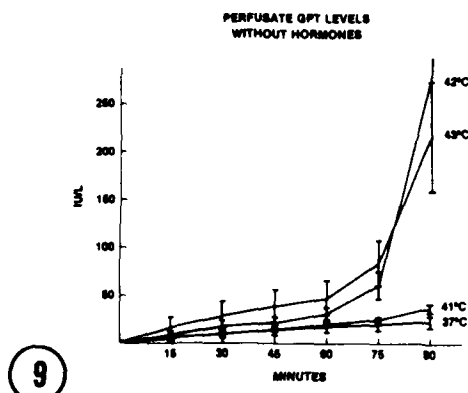
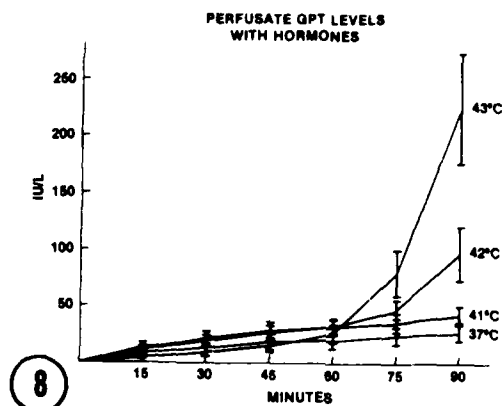
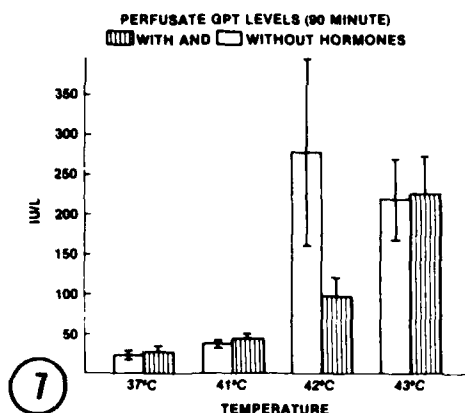
Figure 7 indicates that, in terms of GPT release, only the 42°C group benefited from the treatment. It also confirmed that the 43°C group did not benefit from the treatment. Figure 8 shows marked changes in perfusate GPT after 60 min. at 43°C and 75 min. at 42°C with the treated groups. Figure 9 indicates that similar changes occurred after 60 min at 43°C and 42°C in the untreated groups. GOT leakage followed the same pattern as did GPT (Figs. 10, 11 and 12). These levels of enzyme represent 4-5% of the total intracellular quantity detachable in normal livers.

GPT and GOT leakage reflect changes in membrane permeability sufficient enough to permit passage of protein molecules, a change which occurred late in the heating process when compared to the time course for inhibition of bile production and leakage of potassium.

Except for bile production, which benefited from the treatment at all temperatures, the 37°C, 41°C and 43°C groups displayed no improvement with

treatment. At 37° and 41°C the injury as measured by K<sup>+</sup>, GPT and GOT release was apparently not severe enough to benefit from the treatment while at 43° the injury was so severe that the treatment had no effect. This suggests that 42°C represents a reasonable temperature for testing other drugs. Light microscopy and electron microscopy of these specimens are in progress.





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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161101BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 010 Structural and Functional Alterations in Cells, Tissues  
and Organs Induced by Exposure to Environmental Extremes  
Study Title: Role and Significance of Endotoxin in Heatstroke  
Investigators: David A. DuBose, M.S., Murray P. Hamlet, D.V.M. and  
Wilbert D. Bowers, Jr., Ph.D.

Background:

Stimulation of the reticuloendothelial system (RES) is known to be associated with tolerance to shock and trauma, whereas blockade of the RES results in increased mortality (2). We have recently reported that a state of endotoxin tolerance is associated with reduced mortality after experimental rat heat stress (3). Treatment with endotoxins is one means by which the RES may be stimulated (7). Therefore, the enhanced phagocytic activity associated with endotoxin tolerant rats may explain the noted reduction in mortality after experimental heat stress. This report presents findings on other means of RES stimulation and their effect on the heat stress mortality rate.

Progress:

Two forms of chemical treatment (endotoxin or zymosan), as well as subjection to sublethal heat stress were examined as methods for stimulating the RES. The endotoxin treatment employed was a modification of the methods used previously in which 9 increasing doses of endotoxin were injected into rats over a 3 week period (3). This was modified to 3 doses (0.5, 0.8 & 1.2 mg/kg of body weight) of endotoxin (E. coli 026:B6, Difco, Detroit, MI) administered intravenously over a five day period, with a 72 hour rest between the last endotoxin injection and the testing of RES clearance function. The zymosan treatment employed daily intravenous injections of zymosan (1.0 mg/kg of body weight) for 3 days, with a 24 hour rest period before RES testing. Stimulation by sublethal heat stress involved exposure of rats to sublethal heat stress daily for three days. On the first day, rats were placed in an incubator maintained at  $41.5 \pm 1.0^{\circ}\text{C}$  until they reached a rectal temperature of  $41.4^{\circ}\text{C}$ . At this time,

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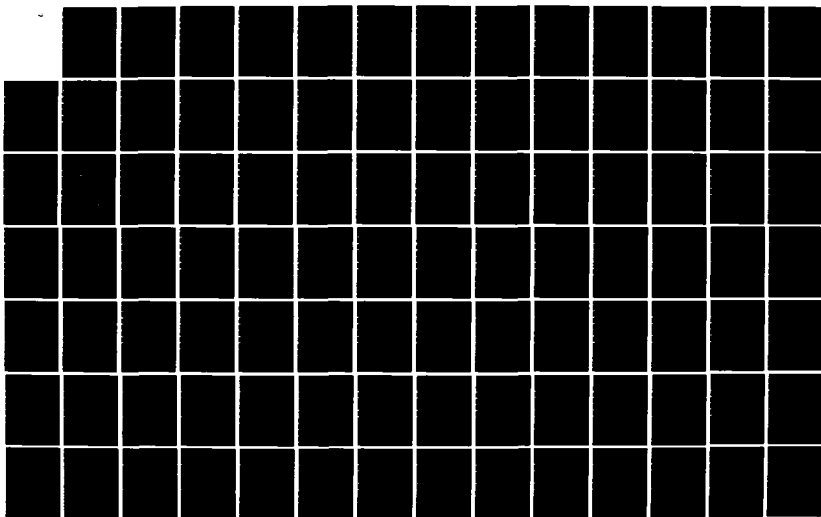
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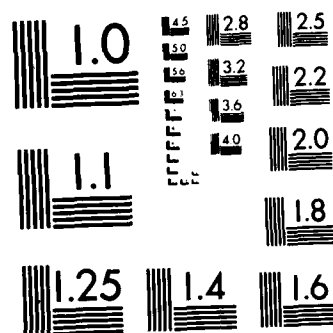
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MICROCOPY RESOLUTION TEST CHART  
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rats were removed from the chamber and allowed to cool to a rectal temperature of  $41.3^{\circ}\text{C}$ , at which time they were returned to the heat stress chamber. This process was repeated until each rat had accrued thermal areas of approximately 35.0 deg-mins, at which time they were removed from the heating chamber and allowed to passively cool. On days two and three the same process was followed, but the maximum rectal temperature that each rat was allowed to obtain, while in the heat stress chamber, was increased to  $41.6$  and  $41.8^{\circ}\text{C}$ , respectively. Twenty-four hours after the last heat stress exposure, RES clearance function was evaluated.

Removal of colloidal carbon from the blood was used to determine RES clearance function. The carbon, Black Pearls 880-CS3989, was kindly provided by Dr. F. Heckman (Cabot, Corp. Billerica, MA). This carbon has a median aggregate size of  $25\text{ }\mu\text{m}$ . It was suspended, in saline containing 5% gelatin, by sonication for 20 minutes at 75 watts of power. Cannulas were placed in the aortic arch and inferior vena cava of the anesthetized rats via the carotid artery and femoral veins, respectively. The aortic arch cannula was used for withdrawing blood samples, while the carbon sample ( $50\text{ mg/kg}$ ) was administered via the inferior vena cava cannula. A precisely timed blood sample was collected 15 minutes post carbon injection. A  $0.1\text{ ml}$  sample of rat blood was placed in  $2.5\text{ ml}$  of  $0.1\text{M}$  sodium carbonate and read in a spectrophotometer at  $650\text{ m}\mu$ . Absorption values were compared to a standard curve of known carbon concentrations in blood, to determine the  $\text{mg}$  of carbon per  $\text{ml}$  of blood in the 15 minute sample.

Other groups of rats, treated to stimulate RES clearance, were subjected to lethal levels of experimental heat stress (3). A comparison of mortality rate between the RES stimulated rats and their controls was then made.

Table 1 illustrates the mean percent of the injected carbon that could be recovered from the liver, lungs and spleen. As shown, a mean of 82.94% of the injected carbon was cleared by these organs. This indicated that the carbon particles were taken up by the major organs of the RES.

All three methods employed to stimulate the RES significantly improved carbon clearance (Table 2). Both sublethal heat stress and endotoxin treatment were associated with significant tolerance to lethal heat stress, whereas zymosan treatment was not (Table 3).

TABLE 1

Mean Percent of Carbon Sample Recovered  
in the liver, lung, and spleen

Number of Carbon Samples	Number of Rats	Liver	Lung	Spleen	Total Carbon Recovered
5	20	60.76 ± 9.78	19.26 ± 7.30	2.92 ± 0.84	82.94 ± 11.06

TABLE 2

Comparison of mean blood carbon concentration  
(mg/ml) 15 mins. post carbon injection between RES  
stimulated rats and non-stiumlated controls.

Method of RES Stimulation	N	Stimulated	Non-Stimulated Controls
Endotoxin	16	0.011* ± 0.009	0.027 ± 0.021
Zymosan	29	0.002* ± 0.004	0.043 ± 0.051
Sublethal	32	0.017* ± 0.017	0.129 ± 0.120

\* significantly different than the control value

These findings are consistent with the literature, in that in all cases where sublethal stress has been employed as a means of stimulating the RES, tolerance to lethal levels of stress has resulted (2). When chemically-induced stimulation of the RES has been employed, results have not been as uniform. In general, treatment with endotoxin has been found to induce tolerance to all forms of shock and trauma tested (1,5,8), whereas other chemical stimuli such as thorotrast, saccharated iron oxide, zymosan and certain triglycerides have not been as consistent in inducing tolerance to stress, even though they do significantly stimulate the RES (2). In the case of stimulation with zymosan, significant protection is afforded to hemorrhagic shock (4) and shock induced by trauma (6)

TABLE 3

Comparison of mortality rate between RES stimulated  
and nonstimulated control rats

Method of RES Stimulation & Controls	N	Mean Max. Temp.	Mean Total Area	% Mortality
Sublethal heat stress	14	42.70 ± 0.39	54.72 ± 2.98	0.00*
Controls	24	42.70 ± 0.26	55.50 ± 2.40	45.8
Endotoxin	11	42.78 ± 0.28	53.89 ± 2.92	27.3*
Controls	13	42.82 ± 0.30	55.27 ± 2.63	84.6
Zymosan	20	42.58 ± 0.27	43.87 ± 3.27	60.1
Controls	24	42.64 ± 0.11	44.93 ± 2.79	67.0

\* significantly different than the control value

and acceleration (8), but zymosan treatment does not offer protection to tourniquet shock, and dramatically increases sensitivity to endotoxin shock (7). Our findings indicate that zymosan treatment does not induce significant protection to heat shock. Lack of correlation between some chemically induced stimulations of the RES and resistance to shock and trauma is thought to be associated with pathological changes induced by these chemical treatments (2).

These findings indicate that as found in other forms of stress, sublethal exposure results in both stimulation of the RES and tolerance to lethal heat stress. In addition, methods of chemically induced stimulation of the RES may or may not result in tolerance to lethal heat stress. Thus, as concluded by previous studies of stresses which can result in shock (1,2,4), the RES may serve as a pathway of host resistance to shock induced by experimental heat stress.

Presentation:

DuBose, D.A., L. Maglione, M. McCreary, and L. Goode. The effects of endotoxin tolerance and other means of stimulation of reticuloendothelial function on survival after experimental rat heat stress. Federation of American Society for Experimental Biology. New Orleans, April 1982. Fed. Proc. 41(4):123S, 1982.

Publication:

DuBose, D.A., K. Basamania, L. Maglione and J. Rowlands. Role of bacterial endotoxins of intestinal origin in rat heat stress mortality. J. Appl. Physiol. Respirat. Environ. Exercise Physiol. 54(1): 1983.

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8. Stiehm, E.F. Acceleration protection by means of stimulation of the reticuloendothelial system. J. Appl. Physiol. 17:293-298, 1962.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E(AR)636	
3. DATE PREV SUMRY <sup>a</sup>	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8. DISSEM INSTR <sup>a</sup>	9. SPECIFIC DATA - CONTRACTOR ACCESS <sup>a</sup>	10. LEVEL OF SUM <sup>a</sup>
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11. NO./CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	61102A	3M161102BS10		CA		011	
B. CONTRIBUTING							
C. CONTRIBUTING	STOG 80-7-4						
12. TITLE (Precede with Security Classification Code) <sup>a</sup>							
(U) Assessment of the Impact of the Environment on Military Performance (22)							
13. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup>							
013400 Psychology; 005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology Stress							
14. START DATE		15. ESTIMATED COMPLETION DATE		16. FUNDING AGENCY		17. PERFORMANCE METHOD	
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18. CONTRACT/GRANT				19. RESOURCES ESTIMATE		20. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				B. PRESENTING		C. FUNDS (in thousands)	
B. NUMBER:				82		5.0	
C. TYPE:				FISCAL YEAR		145	
D. KIND OF AWARD:				CURRENT YEAR		166	
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21. RESPONSIBLE DOD ORGANIZATION				22. PERFORMING ORGANIZATION			
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ADDRESS: NATICK, MA 01760				ADDRESS: NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: KOBRICK, JOHN L., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4855			
SOCIAL SECURITY ACCOUNT NUMBER:				ASSOCIATE INVESTIGATORS			
23. GENERAL USE				NAME: FINE, BERNARD J., Ph.D. POC:DA			
Foreign Intelligence Not Considered				NAME:			
24. KEYWORDS (Precede EACH with Security Classification Code)							
(U) Human Performance in Heat; (U) Human Performance in Cold; (U) Human Performance at Altitude; (U) Sustained Human Performance							
25. TECHNICAL OBJECTIVE, 26. APPROACH, 27. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Operational planning, personnel selection and training, new equipment design and computer simulations used in doctrine and force development require data on how environmental conditions affect individual operator capabilities. This work unit assesses at the level of basic functions the psychological and psychophysiological disruption caused by thermal stress, hypoxia and fatigue which can impair critical military performance before the soldier becomes an environmental casualty.</p> <p>24. (U) Psychological tests and performance tasks are used under controlled conditions in the field and laboratory to quantify decrements in perceptual, cognitive and psychomotor functions of special relevance to the Army. Psychological inventories provide a basis for predicting individuals whose performance is especially susceptible to stress, while psychophysiological measures are used to examine mechanisms underlying the decrements.</p> <p>25. (U) 81 10 - 82 09 Construction is continuing on a combined peripheral visual response and central compensatory tracking measurement system. Data analysis is underway in a collaborative study (USARIEM and LAIR) at Pikes Peak on effects of sustained hypoxia (14,700 ft) on night vision. A book chapter, "Climate and Human Performance", was accepted for publication in "Psychology of Productivity and Work" (Wiley). Data collection has been completed in a study of color discrimination in females. A performance test battery to sample a wide variety of psychological behaviors under environmental extremes is under development, and is based partially on performance tasks taken from the Navy's PETER battery. The battery was tested in a Navy desert field study of SEAL personnel wearing CBR uniforms, and in a USARIEM study of atropine effects.</p>							

<sup>a</sup>Available to contractors upon originator's approval

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 011 Assessment of the Impact of the Environment on  
Military Performance  
Study Title: Field-dependence and Performance of Female Observers on  
the Farnsworth-Munsell 100-Hue Test  
Investigator: Bernard J. Fine, Ph.D.

Background:

The ability to discriminate colors has a seemingly important but as yet relatively undefined relationship with certain military tasks, e.g., target detection and identification, use of camouflage, reading of contour maps.

Relatively little is known about the effect of environmental stresses on color discrimination ability or of differences between individuals in their ability to discriminate colors.

Previous research (Fine, 1973) led to the discovery of a very strong relationship between the personality dimension of field-dependence and color discrimination; field-independent observers were found to be much better color discriminators than field-dependent observers. Further research (Fine and Kobrick, 1980) has strongly established the validity of the original findings.

The field-dependence dimension previously has been related theoretically to differences in various aspects of the nervous system. Thus, the differences between individuals may be quite basic and significant. This is of importance, since the field-dependence dimension has been shown to be related to military tasks such as booby trap detection, identifying targets in aerial photos, identifying targets in the field, motor vehicle operation, monitoring visual information and target detection and location.

All of the data on the relationship between field-dependence and color discrimination has been obtained from male observers. The study reported here was designed to determine if the same relationship holds for female observers.

Progress:

Thirty civilian and military female observers, with ages ranging from 17 to 62 years, were tested for field-dependence, and performed two trials on the Farnsworth-Munsell 100-Hue Test under appropriate standardized lighting conditions.

Data tabulation has been completed; data analysis will be completed in FY83.

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1. Fine, B.J. Field-dependence-independence as "sensitivity" of the nervous system: supportive evidence with color and weight discrimination. Percept. Mot. Skills, 37:287-295, 1973.
2. Fine, B.J. and J.L. Kobrick. Field-dependence, practice, and low illumination as related to the Farnsworth-Munsell 100-Hue test. Percept. Mot. Skills, 51:1167-1177, 1980.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 011 Assessment of the Impact of the Environment on  
Military Performance  
Study Title: Assessment of Night Vision and Other Related Measures  
During Extended Hypoxia  
Investigator: John L. Kobrick, Ph.D.

Background:

This study was intended to augment and extend the findings of a previous study of the effects of short-term hypoxia exposure on night vision. In the present project, a computer-controlled dark adaptometer developed at Letterman Army Institute of Research (3) was employed to obtain night vision thresholds along with selected related measures during a field study conducted at the USARIEM High Altitude Facility at Pikes Peak, Colorado.

Progress:

Eight soldier volunteers were first screened for normal vision and then were trained to perform the following experimental tasks:

Dark adaptation: In a darkened room, subjects adjusted recurrently flashing red and green test lights to their threshold levels of detectability over a 20-minute test period. The system is computerized to store the data and also operate a curve plotter which graphs the continuous dark adaptation threshold function (3). A comparison test of night vision threshold using a conventionally-designed manually-operated night adaptometer was also employed.

Accommodation and night focus: Subjects adjusted the position of two luminous bars projected through a polaroid filter system to apparent equality, providing a measure of the relaxed night focus in diopters (2,4).

Binocular vergence: This measure was obtained as a comparison value to accommodative focus, in which binocular convergence under reduced illumination was measured in diopters through a crossed polaroid filter system (1).

Subjects were first trained under sea level conditions and were then transported by aircraft and ground vehicle to Pikes Peak, where they were tested on all measures at two-day intervals during a sojourn of 16 days. Data analysis is underway. Preliminary results indicate significant elevations of dark adaptation thresholds (1+ log units) for the majority of subjects, which became progressively more severe with continued exposure, and showed little recovery. Also, a significant improvement in sensitivity was noted shortly after a brief excursion to a lower elevation (8000 ft.) on the eleventh day of exposure, followed soon by restored impairment upon return to the original higher elevation. Differential sensitivity to red and green stimuli was also noted for most subjects. Data analysis is continuing.

#### LITERATURE CITED

1. Johnson, C.A. Effects of luminance and stimulus distance on accommodation and visual resolution. *J. Opt. Soc. Am.* 66:138142, 1976.
2. Leibowitz, H.W. and D.A. Owens. New evidence for the intermediate position of relaxed accommodation. *Docum. Ophthalmol.* 46:133-147, 1978.
3. O'Mara, P.A., H. Zwick and C.W. VanSice. A microcomputer controlled solid-state dark adaptometer. Technical Report, Letterman Army Institute of Research, San Francisco, CA, 1980.
4. Simonelli, N.M. Polarized vernier optometer. *Behav. Rsch. Methods Instru.* 12(2):293-296, 1980.

Program Element: 61.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 011 Assessment of the Impact of the Environment on  
Military Performance  
Study Title: Assessment of Night Vision and Other Perceptual  
Performance During Hypoxia  
Investigators: John L. Kobrick, Ph.D., Bernard Fine, Ph.D. and Peter  
O'Mara, MAJ, MSC

Background:

The increasing importance of night operations in military planning has created a growing need for better understanding of and information about the range and limits of night vision capability. Although the basic human dark adaptation function has been well documented, human night vision capability is known to be variable and inconsistent between individuals, and cannot be accurately specified for the Army population based on available group average dark adaptation functions (2). Night vision is also known to be influenced by other situational factors, such as environmental stress, particularly hypoxia. The present project is a collaborative effort between this Institute and Letterman Army Institute of Research to assess the effects of levels of hypoxia on night vision using the USARIEM hypobaric facility, and a new computerized adaptometer developed by LAIR. Other visual indices presumed to be related to night visual capability (accommodation and night focus, vergence, linear distance judgment, luminance threshold for target detection) are also of interest for comparison with night vision threshold performance curves.

Progress:

Nine soldier volunteers were screened first for normal vision, and then were trained intensively to perform the following experimental tasks:

Dark adaptation: In a darkened room, subjects adjusted recurrently flashing red and green test lights to their threshold levels of detectability over a 20-minute test period. The system is computerized to store the data and also operate a curve plotter which graphs the continuous dark adaptation threshold function (6).

Accommodation and night focus: Subjects adjusted the position of two luminous bars projected through a polaroid filter system to apparent equality, providing a measure of the relaxed night focus in diopters (5,7).

Binocular vergence: This measure was obtained as a complementary value to accommodative focus, in which binocular convergence under reduced illumination was measured in diopters through a crossed polaroid filter system (4).

Linear distance estimation: Subjects estimated the apparent distance of a military target appearing at a variety of apparent distances in a series of projected slides (3).

Two-axis compensatory tracking: This measure has been shown previously to be sensitive to hypoxia exposure, and was included to obtain additional performance data under a series of hypoxia exposures, although unrelated to night vision. Subjects attempted to maintain a random-moving cursor by compensatory manipulation of a two-axis manual joystick (1).

Following training, subjects received different combinations of daily exposures to hypobarically simulated altitudes of 11,000, 13,000, and 15,000 feet for periods of eight hours each, at weekly intervals. Within each period, they were tested repeatedly on the measures described above.

Data collection was completed, and data analysis is underway. Preliminary results indicate significant elevations in dark adaptation thresholds in direct relation to the progressive severity of hypoxia exposures, but not for all subjects. Other data indicate significant impairment of binocular vergence in some subjects. Data analysis is continuing.

#### LITERATURE CITED

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2. Fisher, K.E. and C.J. Carr. A study of individual variability in dark adaptation and night vision in man. Life Science Research Office, FASEB, Bethesda, MD, 1969.
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5. Leibowitz, H.W. and D.A. Owens. New evidence for the intermediate position of relaxed accommodation. *Docum. Ophthalmol.* 46:133-147, 1978.
6. O'Mara, P.A., H. Zwick and C.W. Van Sice. A microcomputer-controlled solid-state dark adaptometer. Technical Report, Letterman Army Institute of Research, San Francisco, CA, 1980.
7. Simonelli, N.M. Polarized vernier optometer. *Behav. Rsch. Methods Instru.*, 12(3):293-296, 1980.

Program Element: 61.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 011 Assessment of the Impact of the Environment on  
Military Performance  
Study Title: Development of a Multibehavioral Task Battery for  
Evaluating the Impact of the Environment on Performance  
Investigators: L. E. Banderet, Ph.D. and J. L. Kobrick, Ph.D.

Background:

Studies of human capabilities and efficiency during exposure to stressful environments sometimes produce unexpected results, i.e., performance is not impaired or may improve. Although such effects may occur, they must be regarded skeptically until the sensitivity of dependent measures, the effect of practice, and task reliabilities are known. Unfortunately, dependent measures are sometimes used in studies without such knowledge. Without this information, one cannot determine if findings, such as those cited above, result from lack of dependent measure sensitivity, confounding of environmental and practice effects, etc. To avoid these limitations, a number of tasks with desirable functional or statistical characteristics are being identified for evaluating perceptual, psychomotor, and cognitive functioning. This program is based upon work (2) by the Navy Biodynamics Lab, New Orleans, LA, which is especially appropriate for repeated-measures experiments, evaluating test subjects with various MOSs, and experiments where time for assessment is limited. Some tasks and their alternate forms can be generated by computer. Tasks can be presented on a computer terminal or as paper and pencil tasks for evaluating environmental variables, chemical defense antidotes, and varied therapeutic strategies. Selected tasks in the battery assess unitary and independent behavioral capacities (3). The battery can be used to assess selected skills and capacities for specific MOSs or civilian vocations, and is also suited for collaborative efforts or for use by other investigators.

### Progress:

Collaborative studies and other cooperative efforts are progressing with the Naval Biodynamics Lab. Seven tasks originally developed by the Navy (1) have been generated by computer at USARIEM. Tasks were improved and adapted for our requirements by generating them as paper and pencil tasks on an off-line computer copier, increasing task difficulty, and lengthening tasks for longer test trials. Transparent scoring sheets with the same spatial arrangement as each task make scoring faster, less prone to error, and feasible for one person. Fifteen alternate, but equivalent, forms of each task were created. Two new tasks are currently under development at USARIEM: a computer interaction task and a problem solving task.

A pilot study using all seven tasks was completed during August 1982 using scientific-technical personnel to provide "normative" data and first-hand experience with testing materials and procedures. Two tasks were used in September 1982 during a Navy desert field study with SEAL personnel experiencing increasing metabolic heat loads while wearing CBR uniforms. Three tasks were utilized during the USARIEM atropine study (Sep - Oct 82). Data analyses from these efforts are in progress.

The computer interaction task and other tasks from the battery will be used during a series of altitude studies in Dec 82 and Jan 83. Additional evaluations will be conducted during a joint Navy-USARIEM dehydration study (Jan - Feb 83), involving a 5-day cold exposure with heavy physical exercise, and an altitude study (Fall 83) at varying levels of high altitude up to 25,000 ft.

If these initial studies show that the tasks are sensitive to environmental exposure, they will be converted for presentation on computer terminals. Granting initial successes, longer-range goals involve selection and/or development of other tasks to complement the existing battery. Tasks referenced in the scientific literature and suitable commercial electronic games and devices will be used, when possible, to reduce development time and effort.

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3. Personal communication with R.S. Kennedy, Ph.D., Canyon Research Group, Orlando, FL, August 1982.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E(AR)636	
3. DATE PREV SUM <sup>a</sup>	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
82 04 30	D.CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO./CODES <sup>a</sup>		PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER	
A. PRIMARY		61102A		3M161102BS10		CA	
B. CONTRIBUTING						014	
C. COOPERATING		STOG 80-7.2:4					
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U) Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 005900 Environmental Biology; 010100 Microbiology; 002300 Biochemistry							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
77 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PRECEDING		B. FUNDS (In thousands)	
B. NUMBER: <sup>a</sup>				FISCAL		82	
C. TYPE:				YEAR		CURRENT	
D. KIND OF AWARD:				83		1.5	
E. AMOUNT:						40	
F. CUM. AMT.						47	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME. IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> BRUTTIG, STEPHEN, CPT, MSC, Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4861			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: HAMLET, MURRAY P., D.V.M.			
				NAME: POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tissue Culture; (U)Endothelial Cells; (U)Hypothermia; (U)Frostbite; (U)Ultrastructure; (U) Platelets							
23. TECHNICAL OBJECTIVE. <sup>a</sup> 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Frostbite injuries to military troops result in a prolonged recovery time, sometimes in excess of one year. In frostbite, endothelial cells suffer a freeze-thaw insult when an extremity freezes. Such damage often leads to microvascular hemostasis (which may involve platelet aggregates) which is initiated by direct endothelial freeze-thaw damage. This blood-flow stasis may lead to significant tissue necrosis. Therefore, this study has developed an <i>in vitro</i> method suitable for studying platelet-endothelial interactions on platelet aggregation, and specifically any cold-induced endothelial cell enhancement of platelet aggregation.</p> <p>24. (U) Incubations of calf endothelial cells at control (37°C) or low temperature (24°, 4°, 0.5°C) were conducted utilizing either monolayer cultured endothelial cells or segments of either aorta or portal vein. Media from cultured endothelial cells was tested for its effect on platelet aggregability. Platelet aliquots (taken from cell cultures or blood vessel segments) were reacted with a standard dose (15 µg) of aggregating agent (ADP) to determine any changes in aggregability.</p> <p>25. (U) 81 10 - 82 09 The <i>in vitro</i> endothelial cell model was used to study the effects of cold on platelet-endothelial cell interaction. Preliminary results indicate that media from cold-incubated endothelial cells does not cause or enhance platelet aggregation. In addition, the results show quite dramatically (confirming other studies) that viable endothelial monolayers inhibit platelet aggregation; an effect which was blocked by incubation with aspirin (1.3 mg/ml) and thus implicates the synthesis of prostacyclin by these endothelial cells. This endothelial cell-mediated inhibition of platelet aggregation was little effected by cold. Although preliminary, these data indicated that viable endothelium is not responsible for the aggregates of platelets observed in the capillaries of frostbitten tissue.</p>							

<sup>a</sup>Available to contractors upon originator's approval

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161101BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 014 Cell Culture Modeling of Cellular Disabilities  
Associated with Environmental Extremes  
Study Title: Effects of Cold Stress on Endothelial Cell-Induced Platelet  
Aggregation  
Investigators: Stephen P. Bruttig, CPT, MSC, Ph.D. and Murray P. Hamlet,  
D.V.M.

Background:

The specific interaction of platelets with damaged endothelial cells is not well known (1). However, mural thrombi, emboli and aggregates of platelets in the microvasculature are the commonly described features in the pathology of frostbite (2,3,4). The platelet aggregation seen in these areas of blood flow stasis can be caused by a number of physiological factors (e.g., adenosine diphosphate = ADP, epinephrine, collagen, thrombin, etc.; (5), but whether these or other factors or their effects are perturbed in frostbite is unknown. There is evidence to show that some of the clotting factors are altered in the systemic circulation in response to frostbite, but since the damage due to frostbite is a local phenomenon, there is no information concerning these factors in the local vascular bed.

In this investigation, primary attention was focused on the effects of non-freezing cold on the interaction between platelets (bovine or porcine) and large blood vessel endothelium (bovine aortic and portal venous, porcine aortic). Specific attention was focused on alterations in ADP-induced platelet aggregation, when platelets were exposed either to endothelial cell media from various temperatures, or to the cells themselves at various temperatures.

In order to extend these experiments to functional small vessels, we also have performed experiments to characterize the hydrodynamic properties (pressure-flow-filtration relations) of an "artificial capillary" bundle (Amicon; Danvers, MA). These experiments were performed in preparation for seeding the luminal surface of these "capillaries" with endothelial cells and studying endothelial cell function (in a pulsatile, flow-through system) in relation to cold.

### Progress:

Bovine (calf) platelets were isolated by centrifugation and either filtered through Sepharose 2-B (Pharmacia, Piscataway, NJ) (= GFP) or re-suspended in Tyrodes' buffer with 0.2% bovine serum albumin (= UNF). These platelets aggregated quickly in response to ADP, and in a dose-dependent fashion. Curiously however, there seemed to be little effect of exogenous adenosine on aggregation of these platelets; adenosine added to other platelet systems increases platelet cyclic AMP and inhibits ADP-induced platelet aggregation (6). When these platelets were exposed to incubation media (Tyrodes' plus albumin) from cooled, cultured endothelium, there was no initiation or enhancement of platelet aggregation, yet each sample aggregated quickly in response to a standard dose of ADP. The aggregation of cooled platelets (to 0.5°C) was unimpaired compared to 37°C controls; however, all platelet samples were aggregated at 37°C, regardless of incubation temperature. Platelets incubated in the presence of cultured bovine endothelium were always slow to aggregate in response to ADP. This degree of inhibition was directly proportional to incubation time (the greater inhibitions at the longer incubation times) and was not sensitive to incubation temperature. This inhibition of aggregation, described by other investigators (7,8), was blocked by incubation in aspirin, and was attributed to the production of prostacyclin (PGI<sub>2</sub>) by endothelial cells (9).

Like bovine platelets, porcine platelets (both GFP and UNF) aggregated quickly to a standard dose of ADP, with an ED<sub>50</sub> of approximately 1.0 µM. Porcine platelets responded in a dose-dependent and time-dependent fashion to the addition of exogenous adenosine. Thus, as adenosine is added to platelet mixtures, the speed and degree of aggregation are predictably diminished. Porcine endothelial cells also inhibited platelet aggregation, but to a lesser degree than bovine cells. In addition, this endothelial cell-induced inhibition of platelet aggregation was significantly diminished at temperatures lower than 24°C, although the mechanism to explain this phenomenon is unknown.

This difference in aggregation response between porcine and bovine platelet-endothelial cell systems has not been described previously and is unexplained at the present time. The loss of "protection" by porcine platelets at temperatures lower than 24°C may have significance if these cells resemble the

human platelet-endothelial cell system. If this analogy exists, it would predict that as the vasculature is cooled (not frozen), platelets would become more and more susceptible to aggregation in response to physiologic (ADP) stimulation. Further, it is known that damaged cells in general release a variety of nucleotides, including ADP. Thus, if the porcine cells represent the human predicament, the conditions exist to explain some of the embolic phenomena observed in the frostbitten microvasculature.

With respect to the hydrodynamic responses of the "artificial capillary", these experiments only served to show that these "capillaries" behave in a predictable fashion for both pressure-flow and pressure-flow-filtration analyses. In fact, the filtration coefficient for water (CFC), even without an endothelial lining, is in the range of the human glomerulus. Thus, the cell-lined "capillaries", if successful, should behave much like peripheral capillaries (e.g., muscle or skin). Interestingly, the addition of small amounts of bovine serum albumin to the perfusate (to 1.0%) sequentially reduced CFC. CFC returned as the albumin was withdrawn from the perfusate.

These experiments with the "artificial capillary" bundle corroborate and have a direct bearing on data recently presented at FASEB (1982) by a group working with isolated mesentery of the frog. In fact, these data may serve to show that the phenomenon described in the frog mesenteric microvasculature is attributable to the physical properties of albumin and small pores, rather than to the endothelial cell itself.

#### Publication:

Bruttig, S.P., G.D. Draper and M.P. Hamlet. Investigations into initiation or enhancement of platelet aggregation by cooled vascular endothelium. Research Newsletter (published by MRDC) 6:6-7, 1982.

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9. Bruttig, S.P., G.D. Draper and M.P. Hamlet. Investigations into initiation or enhancement of platelet aggregation by cooled vascular endothelium. *Research Newsletter* (published by MRDC), 6:6-7, 1982.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD DR&E(AR)636	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
82 04 30	D.CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO./CODES: <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	61102A	3M161102BS10		CA		015	
B. CONTRIBUTING							
C. COORDINATING	STOG 80-7.2:4						
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U) Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 007900 Occupational Medicine; 012500 Personnel Selection, Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
79 05		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PREVIOUS		B. FUNDS (In thousands)	
B. NUMBER: <sup>a</sup>				82		6.0	
C. TYPE:				FISCAL YEAR		87	
D. KIND OF AWARD:				CURRENT		6.0	
E. CUM. AMT.				83		134	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> SAMPSON, JAMES B., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4855			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATOR			
				NAME: KOBRICK, JOHN L., Ph.D.			
				NAME: POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U) Survey Analysis; (U) Symptoms Self-Reports; (U) Questionnaires/Interviews; (U) Climatic Exposure; (U) Health Risk Factors; (U) Rating Scales							
23. TECHNICAL OBJECTIVE. <sup>a</sup> 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Data are needed on the number and type of Army personnel who suffer environmentally-related illness and injury; on therapies used; on troops exposed but never requiring treatment; on partially disabling symptoms which go unreported; on the nature of exposure (especially related to MOS duties); and on medical risk factors due to individual background, physical condition and health-related behaviors. Such data, obtained from Army populations, give focus to research, prophylaxis and training, and are of direct use to planners, commanders, and at-risk individuals.</p> <p>24. (U) Test specific methodologies for data collection and analysis from personnel in climatic extremes and/or sustained operations during field maneuvers, special training, transmeridian deployments, lab studies and in rigorous physical fitness programs. Questionnaires, interviews, record surveys and behavioral observations obtain subjective and objective data on illness and injury, as well as relevant background information. The methodology is also used in controlled laboratory experiments. Biases introduced by use of volunteer subjects are evaluated and survey sampling statistics are applied to describe subjects in terms of percentiles in Army subpopulations.</p> <p>25. (U) 81 10 - 82 09 Medical complaints were surveyed during the exercises Snow Eagle '82 (Ft. Drum) and Gallant Eagle '82 (Ft. Irwin). During Snow Eagle, each medical treatment facility was monitored with a medical log book, and all individuals reporting adverse weather injuries were interviewed. Data reveal a large number of minor cold hand injury complaints that might have been more serious if under combat conditions. Major causes of injuries were due to inexperience with severe cold weather. Many minor cold injuries were noted also during the desert exercise Gallant Eagle. Troops were unprepared to handle the unusually cold conditions. Rapid action by commanders resolved the problems. Preconceptions about desert environments may prevent adequate preparation for the real variability of weather in deserts.</p>							

<sup>a</sup> Available to contractors upon originator's approval

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disabilities, Injuries  
and Health Hazards  
Work Unit: 015 Survey Analysis of Environmental Medical Symptoms  
and Risk in Army Personnel  
Study Title: Survey Analysis of Medical Complaints During Army Cold  
Weather Exercise "Snow Eagle '82"  
Investigators: James B. Sampson, Ph.D., Earl S. Stein, CPT, MSC  
(MOBDES) and Jared B. Jobe, CPT, MSC, Ph.D.

Background:

Insufficient data are available on the number and type of Army personnel who suffer environmentally-related illness and injury. There is also inadequate information on risk factors due to individual background histories, experience, attitudes, physical training and health under conditions of adverse weather and combat operations. Current scientific data do not allow confident estimates on expected adverse weather injury rates under combat conditions.

The objective of this project is to develop USARIEM's capability to collect and analyze Army data on problems of environmental epidemiology, using the techniques of survey sampling. Specific methods for data collection and analysis are developed and tested during field maneuvers or special training in extreme climates. Survey instruments include specially designed medical record forms, questionnaires, structured interviews and behavioral observations and systematic recording of operational and weather events. Surveys are conducted in cooperation with medical service support units and have minimal effect on overall maneuver operations.

Progress:

Medical complaints were systematically recorded during January cold weather exercise "Snow Eagle '82" at Fort Drum, New York. Data were collected at the hospital dispensaries and at each unit's medical treatment facility. Special coding sheets and a medical classification system were incorporated at each medical facility and monitored by research team members. Each patient who reported an adverse weather injury was interviewed for

information relating to the injury. Additional data were collected on population size, personnel structure, and operational events.

The weather conditions during this exercise were quite severe with frequent blizzard-like storms and low windchill values. Cold injury complaints were at least three times greater than during the previous two studies. Unlike the prior studies, hand injury complaints were the most significant. Both inadequate handwear and poor judgment by inexperienced personnel were judged to be the primary cause of the reported injuries. Other medical problems, however, show the same pattern of frequency as in previous research. In order of significance, the incidence of the major complaints over the 12 day period were as follows (number of individuals per day per 1000 population): Orthopedic (4.67), Respiratory (1.5), Dermatological (.92), Miscellaneous (.92), Adverse Weather Injury (.81), and Dental (.67).

Table 1 compares the percent of injury/illness complaints between Ft. Drum and exercising unit personnel. The largest difference between the two populations was as follows: The exercising units had 18.16% more orthopedic, 6.49% more respiratory, and 6.18% more cold injury complaints than the Ft. Drum, population; while the Ft. Drum personnel had 21.67% more dental, 15.43% more miscellaneous, and 2.45% more dermatological complaints. Exercising units also had higher acute traumas (4.07% more), neuropsychiatric (3.09%), and ENT (2.53%) complaint rates.

Whether these differences reflect consistent differences between an exercising unit and a garrison unit await further study. Cold injury differences are very likely related to exposure factor differences between the two populations but, again, additional studies will be required.

TABLE 1  
Percent of Total Complaints per Population

<u>Complaint</u>	Ft. Drum (N=262)*	Exercising Unit (N=442)*	$\Delta$
	%	%	
1. Respiratory	5.73	12.22	- 6.49
2. Gastrointestinal	4.58	3.85	.73
3. Dermatological	9.92	7.47	2.45
4. Neuropsychiatric	.76	3.85	-3.09
5. Genito-Urinary	2.67	2.94	-0.27
6. Acute Trauma	1.15	4.07	-4.07
7. Orthopedic	19.85	38.01	-18.16
8. Ear, Eye, Nose, Throat	2.67	5.20	-2.53
9. Ophthalmological	1.53	1.81	-0.28
10. GYN	.76	.23	.53
11. Adverse Weather Injury	.38	6.56	-6.18
12. Dental	27.10	5.43	21.67
13. Miscellaneous	22.90	7.47	15.43

\*N = no. of total complaints per population.

Publication:

Sampson, J. B., J. W. Stokes, J. G. Barr and J. B. Jobe. Injury and illness during cold weather training. Military Medicine. (In press)

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY  
Project: 3M161102BS10 Research on Military Disability Injuries and Health Hazards  
Work Unit: 015 Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel  
Study Title: Symptomatology and Psychomotor Performance at Altitude  
Investigators: James B. Sampson, Ph.D., John L. Kobrick, Ph.D. and John T. Maher, Ph.D.

Background:

Insufficient data are available on the number and type of Army personnel who suffer environmentally-related illness and injury. There is also inadequate information on risk factors due to individual background histories, experience, attitudes, physical training and health under conditions of adverse weather and combat operations. Current scientific data do not allow confident estimates and expected adverse weather injury rates under combat conditions.

The objective of this project is to develop USARIEM's capability to collect and analyze Army data on problems of environmental epidemiology using the techniques of survey sampling. Specific methods for data collection and analysis are developed and tested during field maneuvers or special training in extreme climates. Survey instruments include specially designed medical record forms, questionnaires, structured interviews and behavioral observations and systematic recording of operational and weather events. Surveys are conducted in cooperation with medical service support units and have minimal effect on overall maneuver operations.

Progress:

Support was given to the University of Colorado contracted study entitled "Acute Adaptation to High Altitude." Thirteen subjects were tested first at Denver then five days atop Pikes Peak. Subjects were evaluated on five psychomotor performance tasks and the Environmental Symptom Questionnaire (ESQ) daily throughout the study. The performance tasks involved a continuous performance task, a memory task, a digit symbol substitution task, a letter search task, and a vigilance task. Written and computer versions of the ESQ were administered several times each day.

Results show sickness scores follow the expected pattern of acute mountain sickness with morning scores being highest each day. Group scores show the peak of sickness on the morning following the day of arrival. However, great individual variability was also evident. Subjects who were relatively symptom free the first two days had significant symptoms on the third day.

Preliminary analysis of performance data show no effect of altitude. The literature on this issue is mixed. Best estimates are that any psychomotor effects which might occur at 14,000 ft. are easily compensated for by increased effort and concentration. There is also no clear link between altitude sickness other than through motivational intervention.

Symptom questionnaire data have been added to the data from previous research and factor analysis conducted. Analysis shows nine major factors, the first two being two forms of acute mountain sickness, labeled AMS-1 and AMS-2. AMS-1 is the classic syndrome involving headache, dizziness, nausea, loss of appetite and general sickness. AMS-2 is predominately a combination of gastrointestinal and respiratory symptoms which include the items of stomach ache, nausea, back pain, short of breath, hard to breathe, hurts to breathe and depression. In plotting these scores across times we find two separate patterns (Fig. 1). AMS-1 continues to increase until day three then declines rapidly, while AMS-2 shows an immediate peak on the first morning then gradually falls over the next few days. These data suggest that there is possibly more than one kind of acute altitude sickness and each has a different time course. Future research will examine these results.

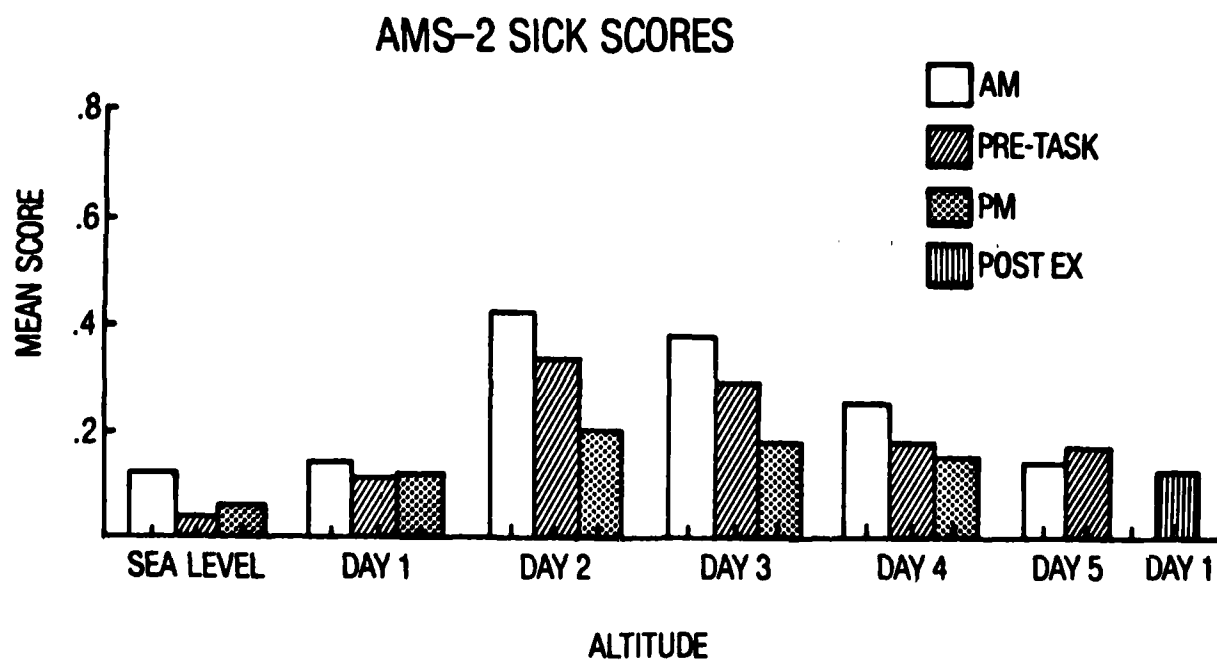
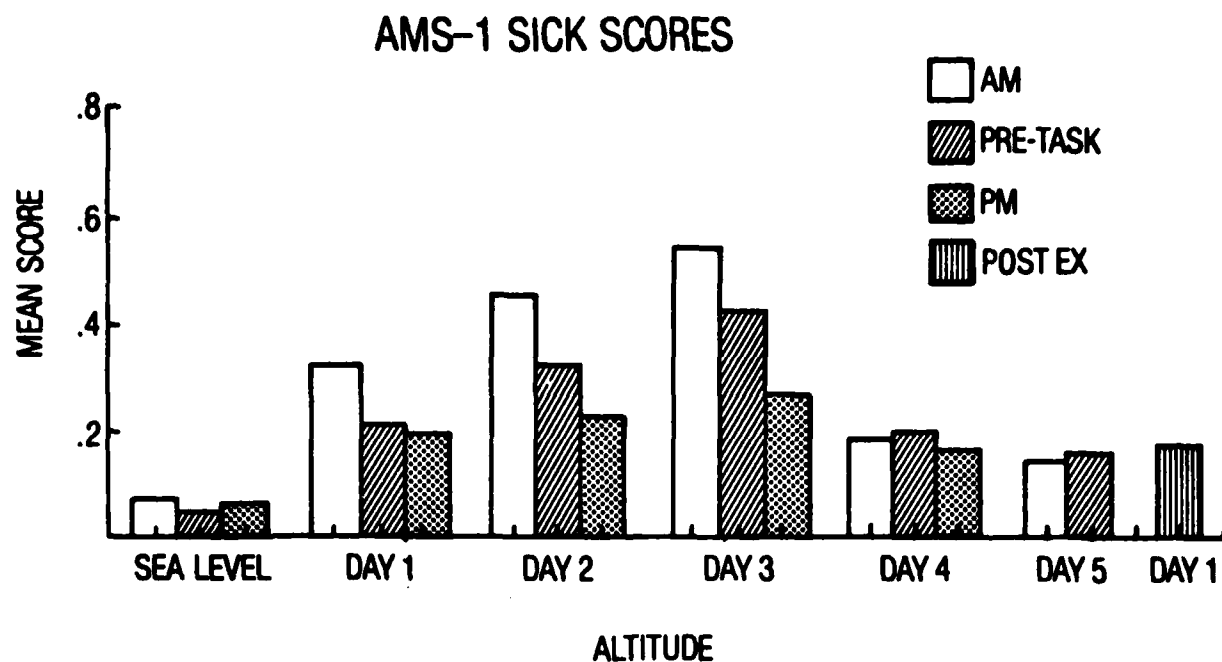


Figure 1. Comparison of AMS-1 and AMS-2 across time at altitude.

FOR REVIEW

(041)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL	
				DA OG 5996	82 09 30	DD-DR&E(AR)636	
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
82 04 30	D.CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO. CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	62734A	3M162734A875		AN		041	
B. CO-PRIMARY	62772A	3S162772A875		BE			
C. CO-PRIMARY	STOG 80-7.2.1						
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U) Work Limitations Induced by Antidotes to CW Agents (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 016200 Stress Physiology; 012900 Physiology; 005900 Environmental Biology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
80 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT GRANT				18. RESOURCES ESTIMATE		19. FUNDS (In thousands)	
A. DATES/EFFECTIVE		EXPIRATION:		PRECEDING		9.0	
B. NUMBER <sup>a</sup>				82		430	
C. TYPE		D. AMOUNT:		CURRENT		12.0	
E. KIND OF AWARD		F. CUM. AMT.		83		450	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> JOYCE, BRENDAN E., COL, MSC, Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-5126			
21. GENERAL USE				22. ASSOCIATE INVESTIGATORS			
Foreign Intelligence Not Considered				NAME: HUBBARD, ROGER W., Ph.D.			
				POC:DA			
23. KEYWORDS (Precede EACH with Security Classification Code) (U)Antidote; (U)Heat Stress; (U)CW Agents; (U)Performance Limits; (U)Work Capacity; (U)Altitude; (U)Laboratory Animal; (U)Human Volunteer							
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Protective measures used against CW agents can result in side effects which may degrade military performance. This work unit is assessing the physiological limitations imposed on the individual by single or multiple protective regimens and the environment.</p> <p>24. (U) Animal models are assessed (a) for their applicability in atropine studies to delineate the dose-response and toxicity alteration with respect to the effects of heat and potential heat-antidote synergy; (b) for possible dose-related effects in the hypoxia of altitude. Studies in human volunteers will be made to determine the degree and nature of side effects of antidotal and protective measures and the nature of military task performance decrements. Laboratory and field studies will be made to enhance combat crew performance in a CW environment and to provide medical input to developers of CW protective clothing and equipment.</p> <p>25. (U) 81 10 - 82 09 An atropinized heat-stressed rat model was developed. Compared to controls, rats given a dose equivalent to that of 2 mg in humans showed a 76% reduction in time to lethal hyperthermia, a 4x increase in heating rate, a 38% reduction in evaporation rate, no significant performance decrement at 5°C or 26°C, significant elevation in skin temperature of exhausted-atropinized rats, significant reduction in mortality rate of the exercised-atropinized group. Preliminary results in rats indicate that moderate concentrations of cholinesterase inhibitors can be tolerated without apparent effects on physical performance, thermoregulation or clinical chemical indices of heat injury. The data collection phase of a study in human volunteers to critically assess the effect of atropine on military task performance began and is presently continuing. Data obtained from human volunteers suggest that trained respiratory muscles can increase their output during severely loaded breathing and may minimize the expected impairment to work tolerance caused by individual protective devices to CW agents.</p>							

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Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES  
Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes  
Work Unit: 041 Work Limitations Induced by Antidotes to CW Agents  
Study Title: Auxiliary Cooling by Liquid and Air Ventilated Systems:  
Phase I (Copper Man Assessment) (ME-E3-79)  
Investigator: George F. Fonseca, M.S.

Background:

Biophysical studies investigating the merits of various auxiliary cooling systems are in progress to provide a technical basis for selecting an auxiliary cooling system for combat vehicle crewmen. One method of providing temperature controlled cooling to these combat vehicle crewmen is to use water-cooled undergarments having a continuous flow of cold water through their tubing. Another possible method is to use an air-cooling system that will circulate either 1) just ambient air within the clothing of these crewmen or 2) air that is temperature and relative humidity regulated. All of these auxiliary cooling systems require a continuous source of energy and some form of connecting hoses or lines. The ice (water) packets vest is an alternative auxiliary cooling system. This auxiliary cooling system does not require a continuous source of energy or any umbilical connections but has the disadvantage that it does not provide continuous, controlled cooling to the wearer; it provides an initial high rate of cooling which tapers off to zero cooling with continuous use. During its operating lifetime, however, it can provide cooling to an air or combat vehicle crewman independently of any vehicle energy. It thus has specific application for short sorties from fixed bases.

Progress:

The auxiliary cooling provided over the torso area by each of two similar ice (water) packets vests was directly measured on a life-sized sectional manikin. These vests were worn with a combat vehicle crewman (CVC) ensemble plus a complete chemical protective (CW) suit. Cooling rates provided (watts) versus time were determined for a completely wet (maximal sweating) skin

condition during heat exposure to three hot environments. The number of ice packets attached to a vest varied from 43 to 91 ice packets. The duration of cooling varied from a minimum of two hours for the experiment when 40% of the ice packets were removed from vest #1, to a maximum of four hours for the results obtained with vest #2. This type of ice packets vest with the maximum number of ice packets (91 ice packets) is capable of providing a total of about 455 watt-hours of cooling over a four-hour period in each of the three hot chamber environments.

The data for a four-hour cooling period suggests that each additional ice packet added to a vest over and above a basic number of about 46 ice packets provides more efficient cooling over the torso than each additional ice packet added to less than 46 ice packets attached to a vest; 5.4 watt-hours of cooling per ice packet to 4.2 watt-hours of cooling per ice packet, respectively.

Expressed another way, each kilogram of ice which is initially at a temperature of  $-20^{\circ}\text{C}$  ( $-4^{\circ}\text{F}$ ) has the potential of providing about 145 watt-hours ( $12 + 93 + 40 = 145$  watt-hrs per kg) of cooling to the torso surface and/or a hot environment before the melted ice temperature reaches the average torso skin temperature of  $35^{\circ}\text{C}$  ( $95^{\circ}\text{F}$ ). Calculating the efficiency of cooling provided over a four-hour torso cooling period by an ice packets vest based on the potential cooling provided by a kilogram of ice, gives 73% when 91 ice packets are attached to a vest; 69% when 72 ice packets are attached to a vest; a further reduction to 44 ice packets attached to a vest reduces the torso cooling efficiency to 63%. These rough calculations indicate that the cooling efficiency of an ice packets vest should increase with the number of ice packets attached to the vest up to the limit of total torso surface area coverage.

The total rates of heat exchange are equal to the manikin watts measured over the completely wet (maximal sweating) surface area of the head, torso, arms, hands, legs and feet. These total heat exchanges are dependent upon the hot chamber environment in which exposure takes place. The total heat exchange over a four-hour cooling period when 91 ice packets are attached to a vest area 760 watt-hours when exposure is in  $29^{\circ}\text{C}$  ( $85^{\circ}\text{F}$ ), 85% relative humidity environment; 690 watt-hours when exposure is in  $35^{\circ}\text{C}$  ( $95^{\circ}\text{F}$ ), 62% relative humidity environment; and 370 watt-hours when exposure is in  $52^{\circ}\text{C}$  ( $125^{\circ}\text{F}$ ), 25% relative humidity environment. Similar to the condition for the heat exchanges over the torso when the ice packets vest provides no cooling, the

total manikin heat exchange in a chamber environment of 52°C (125°F), 25% relative humidity would be negative indicating that there is a net heat gain from this hot environment rather than a net heat loss. Practically, this heat gain would result in the skin temperatures over the total manikin surface area increasing above 35°C (95°F). Increasing the hot chamber air temperature from 29°C (85°F) to 52°C (125°F) decreases the total heat exchange over the completely wet (maximal sweating) manikin surface area by about 50%.

Since the ice packets vest does not provide continuous and regulated cooling over an indefinite time period, exposure to a hot environment would either be time limited, or involve backup ice packets vests which would require redressing every 2 to 4 hours when the ice in the packets was completely melted and water temperature approached skin temperature. Replacing an ice packets vest would obviously have to be accomplished when a crewman was in a standby position. However, this cooling is supplied noise free and independent of any vehicle energy source or umbilical cord that would limit a crewman's mobility.

For the ice packets vest to be of practical use in the field, the ice packets would have to be frozen on the vest. This would require at least two vests per crewman since time spent in replacing individual ice packets would result in the ice packets warming up and losing cooling potential, plus the loss of a crewman's time. However, one ice packets vest should be adequate for most aircrew missions and a single ice packets vest per man should suffice for the time required to replace a track or to resupply ammunition.

Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES  
Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes  
Work Unit: 041 Work Limitations Induced by Antidotes to CW Agents  
Study Title: Evaluation of an Air Distribution System for ROLAND  
Crewmen (ME-E12-81)  
Investigator: George F. Fonseca, M.S.

Background:

This study was initiated to evaluate an Air Distribution System proposed (and designed) by Hughes Aircraft for ROLAND crewmen. The original comparison was made between this air-cooled system and an earlier model of an Individual Protection Laboratory Air-Cooled Vest, designated IPL ACV #1. Subsequently, a later model Air-Cooled Vest, designated IPL ACV #2 was received and studied using the heated, sectional manikin. These vests were worn with a combat vehicle crewman (CVC) ensemble plus a complete chemical protective (CW) suit. In about half of these experiments, face cooling was provided by supplying cooling air at the inlet of a face piece.

Progress:

A method of comparing the efficiency of cooling provided by an air-cooled undergarment over the surface of a body for various inlet cooling air and environmental conditions is by calculating a cooling efficiency term based on the maximum cooling potential of this cooling air entering the inlet of an air-cooled undergarment. This cooling air supplied to the inlet of an air-cooled undergarment is not returned to a refrigeration unit to be cooled and dehumidified, but rather exits through the clothing to the hot environment. Measurements of the temperature and moisture content of this exiting air could involve an elaborate experimental procedure. A simple and more practical approach is to consider the exiting air to be saturated with moisture at the temperature of the skin surface. If all of the cooling air entering an air-cooled undergarment passes over the skin surface so that the exiting air is moisture saturated at the temperature of the skin surface (i.e., 35°C), then the cooling

efficiency of the air-cooled undergarment would be 100%; if all of this cooling air exits to the hot environment without passing over the skin surface, then the efficiency of cooling would be 0%.

The determination of the maximum cooling potential of the ventilating air entering the inlet of an air-cooled vest is the quantity of heat required to raise the inlet air temperature from its initial value to 35°C, plus the evaporative heat required to saturate this air at a temperature of 35°C. The cooling efficiency for a given air-cooled vest would then be the cooling rate (watts) determined experimentally for exposure to a given hot environment and inlet cooling air conditions divided by the maximum cooling potential available in the cooling air multiplied by 100. This criterion enables a comparison to be made of the cooling efficiency of an air-cooled undergarment under different environmental and inlet cooling air conditions.

The cooling efficiency of these air-cooled vests and ventilated XM-29 Face Piece is based on ventilating air exiting to the hot environment at a temperature of 35°C and saturated with moisture. The IPL ACV #1 has an efficiency of 28%, the IPL ACV #2 has an efficiency of 57% and the Hughes air-cooled vest has an efficiency of 31%. The higher air permeability mesh used in the fabrication of the later model of the IPL ACV apparently permits a greater diffusion of this ventilating air over the surface of the torso-arms-legs area rather than significant quantity of this cooling air exiting from the vest directly through the clothing to the hot environment without providing any significant cooling to these body areas. The cooling efficiency of the ventilated XM-29 Face Piece is only about 20%. Apparently, this efficiency is less than that for the three air-cooled vests because the ventilating air exits from the face area directly to the hot environment without passing over any other surface area of the body.

There is very little difference in the cooling rate (watts) between the IPL ACV #1 and the Hughes Air-Cooled Vest at the lower cooling air flow rates. As this flow rate increases to 10 ft<sup>3</sup>/min, the Hughes Air-Cooled Vest provides about 50% more cooling, but increasing the flow rate to 15 ft<sup>3</sup>/min shows only about a 12% increase. At the low cooling air flows, about 92% of the cooling is provided over the torso for the Hughes Air-Cooled Vest and only about 72% for the IPL ACV #1. At the higher cooling air flows, this percentage decreases to about 55% for both air-cooled vests. The Hughes Air-Cooled Vest provides very little cooling over the arms; cooling air exiting from this vest is essentially directed over the torso or down the legs.

The cooling rate (watts) provided by any of these three air-cooled vests or the ventilated XM-29 Face Piece are dependent not only upon their design but also upon the temperature, relative humidity and flow rate of the ventilating air, plus the air temperature and relative humidity of the hot environment. Considering exposure in a hot environment of  $49^{\circ}\text{C}$  at 11% relative humidity and ventilating air at a temperature of  $32^{\circ}\text{C}$  at 26% relative humidity, for a ventilating air flow rate of  $15\text{ ft}^3/\text{min}$  the cooling rate is 142 watts for the IPL ACV #1 and 159 watts for the Hughes Air-Cooled Vest. At a ventilating flow rate of  $4.5\text{ ft}^3/\text{min}$ , the cooling rate (watts) for the head would be about 33 watts  $\pm 10\%$ .

Considering exposure to a hot environment of  $29^{\circ}\text{C}$  at 85% relative humidity, the cooling rate (watts) for the IPL ACV #1 would be 137 watts and for the IPL ACV #2, 212 watts; inlet cooling air at a temperature of  $21^{\circ}\text{C}$  (10% relative humidity for the IPL ACV #1 and 16% for the IPL ACV #2) and ventilating air flow rate of  $10\text{ ft}^3/\text{min}$ .

Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES  
Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes  
Work Unit: 041 Work Limits Induced by Antidotes to CW Agents  
Study Title: The Effect of Atropine on Human Performance  
Investigators: Brendan E. Joyce, COL, MSC, Ph.D., Kent B. Pandolf,  
Ph.D., Michael N. Sawka, Ph.D., Bruce Cadarette, M.S.,  
Leslie Levine, M.S. and Lawrence Drolet, M.S.

Background:

Atropine acts as a competitive antagonist to acetylcholine (ACh) where it binds to the ACh receptor sites of effector organs, blocking the parasympathomimetic or muscarinic effects exerted by ACh. Atropine prevents the action of ACh on smooth muscle, eccrine sweat glands and the heart, as well as ocular and central nervous system receptor sites. The sympathomimetic or nicotinic effects of ACh are not blocked by atropine and action at voluntary muscles is not affected (3).

Soldiers are authorized (Field Manuals 21-11, 21-40, 2148) to carry (and self-administer when directed) two nerve agent antidote injectors each containing 2 mg. atropine. The effects on the soldier of administering the antidote without the challenge of the nerve agent were studied during the present investigation. Since the effects of atropine are many and varied, the investigation was divided into several segments. The segment described in this report will pertain to atropine's effect on temperature regulation in the heat, during mild exercise in healthy young men.

Progress:

Eight male soldiers served as volunteer subjects for the study. Descriptive values ( $\bar{X} \pm .S.E.$ ) for the subjects were age  $23.5 \pm 1.1$  yrs, height  $174.6 \pm 4.0$  cm, weight  $76.8 \pm 2.9$  kg, and body fat by skinfold  $15.9 \pm 1.8\%$ . All subjects were given complete physical examinations and psychological screenings prior to acceptance in the study.

Testing itself consisted of 12 two-hour heat exposures. Subjects were partially acclimated for four days at  $40^{\circ}\text{C}$  and 30% rh. For the treatment days,

environmental conditions were set at 40°C and 20% rh. During all heat exposures subjects exercised for two 50-minute bouts walking at  $1.34 \text{ m} \cdot \text{s}^{-1}$  on a level treadmill with 10-minute rest intervals preceding and between the exercise sessions. On all the test days subjects wore Temperate Battle Dress Uniforms. Subjects were monitored with three-point skin thermocouples to calculate mean weighted skin temperature, with a Yellow Springs thermister inserted ~ 10 cm beyond the anal sphincter for rectal core temperature, and with ECG leads in the CM 5 position for heart rate. Nude weights were taken before harnessing and dressed weights were taken in the chamber pre- and post-exercise and at midpoint rest with K-120 Sauter precision electronic balances (accuracy  $\pm 10 \text{ g}$ ). Water was given ad libitum on all 12 heat exposure days.

After harnessing on all treatment days, subjects had heart rates as well as skin and rectal temperatures recorded in an antechamber to serve as baseline. Following this, all subjects received an injection in the vastus lateralis muscle just prior to entering the chamber. Varied treatments were given ranging from 0 to 4 mg of atropine daily with a rest day after each treatment. Once subjects were inside the chamber each treatment day the testing schedule remained the same. Expired gas samples were collected at rest both before exercise and between exercise bouts as well as at minute 30 of each exercise bout. These samples were measured for volume with a Tissot gasometer and analyzed for  $\text{O}_2$  concentration with an Applied Electrochemistry S-3A electrochemical  $\text{O}_2$  analyzer and for  $\text{CO}_2$  concentration with a Beckman LB-2 infrared  $\text{CO}_2$  analyzer. Mean weighted skin temperature and rectal temperatures were recorded and plotted every two minutes on an HP-9825B calculator and HP 9872A plotter, and heart rates were continuously radio telemetered to an HP oscilloscope tachometer and recorded every 10 minutes. All water given to the subjects was measured so whole body sweat rate could be calculated. Rated perceived exertion (1) and rated thermal sensations (2) were taken during rest and at minutes 20 and 40 of each exercise session. At the end of testing each day, subjects were released to the Health and Performance group for further tests.

Data analysis on the study is ongoing at present.

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Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES

Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes

Work Unit: 041 Work Limitations Induced by Antidotes to CW Agents

Study Title: Auxiliary Cooling: Comparison of Air-Cooled Versus Water-  
Cooled Vests in Hot-Dry and Hot-Wet Environments

Investigators: Fred R. Winsmann, M.S., Yair Shapiro, M.D., Kent B.  
Pandolf, Ph.D., Ralph F. Goldman, Ph.D., Michael N.  
Sawka, Ph.D. and Michael M. Toner, CPT, MSC., Ph.D.

Background:

A need exists to provide combat vehicle crewmen an individual auxiliary cooling system to dissipate body heat. It is essential for maximum operational effectiveness that troops remain within acceptable physiological heat tolerance limits when operating air and ground combat vehicles in CB and high temperature environments. Current Army equipment and decontamination capabilities require that systems be fought in a closed configuration in CB environments. Heat stress may be more acute in such closed systems under hot or humid conditions. Auxiliary cooling to augment the crew member's normal physiological heat dissipating mechanism must be employed. If auxiliary cooling is not provided, the crew member may experience elevated body temperatures, increased heart rate, and may become a heat casualty.

The purpose of this study was to investigate the feasibility and advantages of three concepts of microclimate cooling systems (air-ventilated, air-cooled and water-cooled vests) for alleviating heat stress from combat vehicle crewmen (CVC) suited in a chemical biological (CB) protective ensemble during mild physical work under hot-dry and hot-wet environments.

Progress:

Twelve male volunteer soldiers served as subjects. All experiments were conducted during late summer months, and therefore the subjects were considered naturally acclimated to the heat. Nevertheless, the twelve subjects were acclimatized for one day by walking on a level treadmill at  $1.34 \text{ m} \cdot \text{s}^{-1}$  for

two 50-minute periods with a preceding and intervening 10-minute rest period, at  $49^{\circ}\text{C}$ , 20% rh,  $1 \text{ m} \cdot \text{s}^{-1}$  wind speed. After this acclimatization day, the subjects were exposed to two environmental variations: a hot-wet climate (HW) ( $T_a = 35^{\circ}\text{C}$ , rh = 75%,  $P_a = 31.6 \text{ Torr}$ ) and a hot-dry solar load climate (HD) with 72 infrared 375-watt lamps ( $T_a = 49^{\circ}\text{C}$ , rh = 20%,  $P_a = 17.6 \text{ Torr}$ , black globe temperature =  $68^{\circ}\text{C}$ ). Wind speed for all conditions was constant at  $1 \text{ m} \cdot \text{s}^{-1}$ .

The 12 subjects were divided into three "tank" crews of four subjects each; each crew composed of a driver, commander, gunner, and loader. The daily exposures lasted 120 minutes in which the subjects rested for 100 minutes and exercised for a total of 20 minutes, divided into 4 periods of exercise (minutes 17-22, 47-52, 77-82, 107-112). The type of exercise differed for the various members within a given crew but was the same between crews and was as follows: bench stepping for the commander (46 cm bench,  $10 \text{ steps} \cdot \text{min}^{-1}$ ), cycling for the driver (50 watts), arm cranking for the gunner (50 watts) and 20 kg weight lifting for the loader (51 cm lift,  $4 \text{ lifts} \cdot \text{min}^{-1}$ ).

During all test exposures, the subjects wore underwear, Nomex coveralls, helmets, hoods, gas masks, Nomex gloves, boots, butyl gloves, butyl boot covers, and a chemical protective semipermeable overgarment. The total insulation of the clothing was 2.4 clo and the vapor permeability index ratio was  $0.15 i_m/\text{clo}$  as measured in the laboratory on a dry and a sweating copper manikin, respectively.

During each day of the experiment each crew used a different cooling system employing either an air- or water-cooled vest. The crews changed cooling devices according to an experimental design utilizing the Latin square method. Two versions of the air vest were evaluated with one ventilated by cooled air and the other by ambient air. Since the ambient-air vest caused significant local skin irritation in the hot-dry climate during the first hour of the first experimental day, this cooling vest was used only for evaluation in the hot-wet environment.

Physiological Measurements and Biophysical Calculations. The metabolic rate during the exercise ( $M_e$ ) period for each of the individual subjects wearing full chemical protective uniforms was measured several days prior to the climatic exposures by collecting two-min expired air samples in Douglas bags. Heart rate (HR) was calculated from R-R (ECG) intervals recorded on a electrocardiograph. The average  $M_e$  was found to be  $430 \pm 40 \text{ W}$ . The time weighted metabolic rate (180 watts) was calculated as:  $\bar{M} = (20 M_e + 100 M_r)/120$ , where  $M_r$  was the resting metabolic rate.

During all exposures, rectal temperature ( $T_{re}$ ) was recorded. Skin temperatures were monitored with a three-point thermocouple skin harness (chest, calf and forearm) and mean weighted skin temperature ( $\bar{T}_{sk}$ ) was calculated according to Burton (1). Heat storage ( $\Delta S$ ) was calculated as:  $\Delta S = 0.965 (0.8 T_{re} + 0.2 \bar{T}_{sk})$  in  $W \cdot kg^{-1}$ . Heart rate (HR) was measured during every working period. Ad libitum drinking was encouraged. Total body weight losses were determined from pre- and post-exposure measurements for calculation of sweat rate. Sweat rate ( $\dot{m}_{sw}$ ) was determined from loss of weight adjusted for water intake and any urine output. Respiratory and metabolic weight losses were considered negligible and were not taken into account (4). Since a large part of the sweat was not evaporated, the difference in nude weight was used to calculate  $\dot{m}_{sw}$  while differences in dressed weight were used as an indicator for evaporative sweat ( $\dot{E}_{sk}$ ); most of the unevaporated sweat remained in the clothing, boots and gloves.

Convective heat transfer ( $H_c$ ), radiative heat transfer ( $H_r$ ), required evaporative cooling for thermal equilibrium ( $E_{req}$ ), and the maximal evaporative cooling capacity of the environment ( $E_{max}$ ) were calculated according to Givoni and Goldman (2,3). Further modification for the extra radiant heat load was computed using the mean radiant temperature ( $\bar{T}_r$ ) as:  $H_r = 0.85 \Delta \bar{T}_r$ ; in  $W$ , where  $\Delta \bar{T}_r = T_a \pm 2.2 V (T_g - T_a)$ , with  $V$  = wind speed in  $m \cdot s^{-1}$ ,  $T_g$  = black globe temperature and  $T_a$  = air temperature in  $^{\circ}C$ . The physiological values for exposure to these climates without any auxiliary cooling have been predicted according to Givoni and Goldman (2,3) for  $T_{re}$ ,  $\bar{T}_{sk}$ , and HR, and by Shapiro et al. (5) for sweat rate.

The results indicated that auxiliary cooling appears to be an effective method of reducing the physiological stress of individuals required to work in hot environments while wearing low permeable clothing. It can be concluded that an air-cooled vest can be used with similar efficiency as compared to a water-cooled vest particularly when mild work is done in moderate to hot environments. The ambient-air vest has less effectiveness in moderate heat and can be harmful to the skin in a very hot climate.

#### Presentation:

Pandolf, K.B., Y. Shapiro, M.N. Sawka, M.M. Toner, F.R. Winsmann and R.F. Goldman. Auxiliary cooling: comparison of air-cooled versus water-cooled vests in hot-dry and hot-wet climates. Fed. Proc. 41:1753, 1982.

Publication:

Shapiro, Y., K.B. Pandolf, M.N. Sawka, M.M. Toner, F.R. Winsmann and R.F. Goldman. Auxiliary cooling: Comparison of air-cooled vs. water-cooled vests in hot-dry and hot-wet environments. *Aviat. Space Environ. Med.* 53(8):785-789, 1982.

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Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES

Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes

Work Unit: 041 Work Limitations Induced by Antidotes to CW Agents

Study Title: Atropinization and the Predisposition to Performance  
Decrements and to Fatal Heatstroke

Investigators: Roger W. Hubbard, Ph.D., Candace B. Matthew, M.A., Ralph  
Francesconi, Ph.D. and Milton Mager, Ph.D.

### Background

Atropine is considered the prototype of a class of drugs which antagonize the muscarinic actions of acetylcholine. Two important manifestations of muscarinic blockade are an increase in heart rate and an inhibition of sweating. Most human protocols involving exercise in the heat and resulting in subject hyperthermia are discontinued if the subject's  $T_{re}$  exceeds  $39.5^{\circ}\text{C}$  or if heart rate exceeds 180 bpm. Since sweat gland inhibition would increase the rate of hyperthermia and vagal inhibition would tend to increase heart rate by approximately 40 bpm (2), then the temperature span over which atropine effects could be safely studied in man is narrowed considerably. These factors, as well as the more obvious moral and legal ones, effectively constrain human studies on the effect of atropine on the susceptibility of the subject to heat disorders during or following a hyperthermic episode. As a consequence of similar considerations, both dog and rat heat illness models (1,5) have been developed. A preliminary study comparing the effects of atropine, surgical desalivation and physical restraint on the thermoregulatory behavior of heat-stressed rats has been completed (6). A dose of atropine (100  $\mu\text{g}$ ) equivalent to a 2 mg dose in humans (4) and compared to a saline control produced the following results: (a) a 76% reduction in exposure time to lethal hyperthermia, (b) a four-fold increase in heating rate and (c) a 38% reduction in evaporation rate. This reduction in evaporation rate was similar to the 42% decrement in sweating and evaporative cooling reported by Robinson using a 2 mg dose (8). Furthermore, in a cool environment ( $26^{\circ}\text{C}$ ) Robinson (8) found that atropine did not seriously interfere with the performance of prolonged moderate work. Based upon the initial promising similarities between the animal model and the human response to

atropine, we decided to evaluate both the performance and toxicity characteristics of the equivalent dose in the rat.

### Progress:

As shown in Table 1, 28 male Sprague-Dawley rats were run to exhaustion on a motor-driven treadmill (6°incline, 11m/min). As had been reported for human subjects no significant decrement in performance, i.e. run time, at either 5 (not shown) or 26°C, ambient, was observed. Robinson reported average skin temperature increases with atropine of 2.5°C during work at 26°C (8). The cutaneous vasodilation and significantly elevated skin temperatures appear to be a specific atropine effect. Comparable increases for the rat are shown in Table 1. Evaporative cooling of the controls could not explain the difference since rat tail skin lacks sweat glands (7). This suggests that atropine possesses a previously unrecognized vasodilatory action not due to subject differences in sweat rate and core temperature. The increasing heat loss by radiation and convection would produce the observed increase in cooling rate.

TABLE 1

Rat Exercise Performance After 100 mg Atropine, I.V.

Group	n	Run Time (min)	% Wt. Loss	EOR <sup>1</sup> T <sub>re</sub> °C	EOB <sup>2</sup> T <sub>sk</sub>	Cooling Rate °C/min	% Mortality
Saline	16	74 ±22	3.7 ±1.4	41.6 ±0.2	30.0 ±2.1	0.046 ±0.019	56
Atropine	12	61 ±16	1.5* ±0.5	41.6 ±0.3	32.2* ±2.0	0.060* ±0.019	8 <sup>+</sup>

<sup>1</sup> End of running.

<sup>2</sup> Dorsal, mid-tail.

\* P < .05 for Student t test between the mean ± SD and the mean immediately above it.

+ Significantly different by Chi-square

In a recent paper by Davies et al (3) on temperature regulation with atropine during prolonged exercise, atropinized subjects maintained a high  $T_{sk}$  independently of metabolic heat production. Although these atropinized subjects demonstrated a higher peripheral tissue heat conductance than controls, this could not be ascribed to atropine per se because of the lower  $T_{sk}$  and greater (nearly two fold) evaporative sweat loss of control subjects. The model data, therefore, suggest that at moderate work loads the increased peripheral tissue heat conductance is due partially to an atropine vasodilator response independent of  $T_{re}$ .

Both heatstroke and organophosphate poisoning demonstrate similar signs and symptoms affecting the central nervous system, cardiovascular system, G.I. tract, respiration, muscles, bladder, and sweat glands. These similarities in the more general pathophysiological cascade suggest some resemblance in both the primary initiating events as well as potential treatments. For example, elevations in the serum enzymes CPK, GOT, and GPT in organophosphate poisoning are thought to be due to convulsions. Like elevations in heatstroke are attributed to direct thermal injury. Perhaps the delineation of the pathways involved in the common symptomatology would result in similar treatments. In this regard, atropine is a treatment of choice for organophosphate therapy and, quite surprisingly, appears to reduce the expected mortality rate (Table 1) in experimental heatstroke. Future experiments will explore the physiological basis for this interesting observation.

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Program Element: 6.27.34.A TOLERANCE AND TOXICITY TO CW AGENTS  
AND ANTIDOTES

Project: 3M162734A875 Tolerance and Toxicity to CW Agents and  
Antidotes

Work Unit: 041 Work Limitations Induced by Antidotes to CW Agents

Study Title: Atropinization and the Predisposition to Performance  
Decrements and to Fatal Heatstroke

Sub-study: Pharmacokinetic Parameters of the Effect of Atropine on  
Thermoregulation in the Heat-Stressed Rat

Investigators: Roger W. Hubbard, Ph.D., Candace B. Matthew, M.A. and  
Ralph Francesconi, Ph.D.

Background:

The classic colorimetric assay for atropine in use in the late 1800s (8) required 5 µg of alkaloid. A 100 fold reduction in the amount that could be detected (0.5 µg) was achieved in 1932 by employing mydriasis of the mouse eye as a bioassay (5). By using the assay, it was estimated that from one-fourth to one-third of the usual oral dose appeared in urine within 24 hours as pharmacologically active drug (5,7). In the early 1950s, the Army Chemical Center in Maryland conducted (1) or contracted (6) research on the physiological effects of atropine. After atropine administration (1), the skin of human volunteers remained dry for most of the two hours of the test. Craig (1) questioned whether atropine flush (3) was a primary effect of atropine or arose indirectly because of the interference with heat balance. Although blood levels of atropine were not measured, sweat rates suggested that the effect of atropine (2 mg, I.M.) was wearing off in the third hour following injection (6). In 1964, Custance and deCandole reported that 75% of normal sweating had returned within the first 90 minutes following a 2 mg dose. Their results were based on the use of a hygrometer-type Sudorimeter (2). More recent experiments using labeled atropine in man indicate the label disappears very rapidly from the blood but urinary excretion occurs at two rates over the first 24 hours; a fast rate with a  $t_{1/2}$  of about two hours followed by a much slower rate with a  $t_{1/2}$  of about 13 to 38 hours. Based on these observations, we hypothesize that in the rat model the effects of atropine on thermoregulation should begin to wane after two hours. The purpose of this pharmacokinetic experiment is to determine the

period of time after atropine administration during which physiological and behavioral thermoregulation are disrupted. A response pattern with a time course similar to the human data would help establish the validity of the animal model (4).

#### Progress:

Forty-eight male Sprague-Dawley rats weighing  $520 \text{ g} \pm 6$  were individually housed at  $26^{\circ}\text{C}$  and allowed free access to food and water until the start of the heat stress. Either saline or 100 ug of atropine (equivalent to 2 mg in humans) was injected into a lateral tail vein; then the rats were returned to their own cages for 30, 60, 90, 120, or 180 minutes of post-injection delay prior to heat-stress. The unrestrained animals were then heat-stressed in a  $41.5^{\circ}\text{C}$  chamber until a Tcore of  $42.6^{\circ}\text{C}$  was reached at which point they were removed to a  $26^{\circ}\text{C}$  chamber to cool.

The results obtained with saline controls and with animals given the atropine 30 minutes before heat stress confirmed our previously published values (4). The parameters listed in Table 1 all show a time course response to atropine. Exposure times required to reach a Tcore of  $42.6^{\circ}\text{C}$  were significantly reduced for the post injection delay periods of 30 min to two hours. By three hours, the exposure times ( $188 \text{ min} \pm 60$ ), although still lower than control values, were not significantly different. The amount of water loss due to saliva spreading, measured as % weight loss corrected for fecal pellet production, paralleled the exposure time.

Heating rate may be the most sensitive measure of residual atropine effect. The rate at 180 min, although approaching the control rate, is still significantly elevated above control levels.

The post-heating cooling rate returns to control values after a 120 min post-injection delay. The severity of hyperthermia calculated as an area from the start of the heat stress to the end of heating (EOH) also returns to control levels after 120 min.

TABLE 1  
Thermoregulation in Heat-Stressed Rats:  
Time Course of Atropine Inhibition

Group	n	Exposure Time (min)	Body Wt. Loss (%)	Heating Rate (°C/min)	Cooling Rate (°C/min)	Area to EOH <sup>1</sup> (0 min)	Fecal Pellets (g)
Saline <sup>2</sup>	8	210 ± 35	7.1 ± 1.1	0.02 ± 0.01	-0.01 ± 10.04	102 ± 24	2.5 ± 1.7
Atropine <sup>3</sup> 30 min <sup>4</sup>	8	56 <sup>+</sup> ± 9	1.2 <sup>+</sup> ± 0.4	0.08 <sup>+</sup> ± 0.01	0.03 <sup>+</sup> ± 0.03	33 <sup>+</sup> ± 9	0.6 <sup>+</sup> ± 0.6
Atropine 60 min	7	79 <sup>+</sup> * ± 29	2.3 <sup>+</sup> * ± 1.2	0.07 <sup>+</sup> ± 0.02	0.04 <sup>+</sup> ± 0.02	53 <sup>+</sup> * ± 24	1.0 <sup>+</sup> ± 0.6
Atropine 90 min	8	100 <sup>+</sup> ± 46	3.2 <sup>+</sup> * ± 1.8	0.06 <sup>+</sup> ± 0.02	0.03 <sup>+</sup> ± 0.03	66 <sup>+</sup> ± 33	2.2 ± 1.4
Atropine 120 min	7	133 <sup>+</sup> ± 58	5.2 <sup>+</sup> * ± 2.2	0.05 <sup>+</sup> ± 0.02	0.01 ± 0.05	92 ± 47	2.3 ± 1.0
Atropine 180 min	9	188 ± 66	6.4 ± 2.2	0.03 <sup>+</sup> ± 0.00	0.00 ± 0.02	92 ± 16	2.7 ± 1.2

<sup>1</sup> End of heat-stress period. See text for details.

<sup>2</sup> Saline, 0.2 ml I.V.

<sup>3</sup> 100 µg in 0.2 ml saline, I.V.

<sup>4</sup> Times of post-injection delays prior to heat stress.

<sup>+</sup> P < 0.05 between mean ± S.D. and saline controls.

<sup>\*</sup> P < 0.05 between mean ± S.D. and that above it.

Fecal pellet production, a measure of gastrointestinal motility inhibited by atropine, returns to control levels after 90 min. This is the shortest pharmacokinetic parameter of atropine that we have measured.

The early work of Craig (1) and Robinson (6) documented the atropine-induced inhibition of sweat production during exercise in the heat. The resulting loss in thermoregulatory ability and increased risk of heat illness prompted Robinson (6) to recommend that "the use of atropine (2 mg) in men during prolonged work in hot environments should be limited to emergency situations only." Rat model experiments verified this concern by demonstrating that dose-equivalent levels of atropine resulted in a 76% reduction in exposure time to

lethal hyperthermia (4). The heat-stress occurred 15 min following atropine injection. Identical results were obtained with a 30 min post-injection delay (Table 1). Some parameters measured return to the control condition after 90 to 120 mins. of post-injection delay. In contrast, control exposure times indicating no atropine effects on thermoregulation require at least a 180 min delay. These results suggest that atropine effects present an increased risk of heatstroke for at least three hours following its use.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1 AGENCY ACCESSION <sup>a</sup>	2 DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD DR&E (AR) 636	
				DA OC 6149	82 09 30		
3. DATE PREV. SUMM'Y	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8. DISB'N INSTR'N	9. SPECIFIC DATA CONTRACTOR ACCESS	10. LEVEL OF SUM
81 10 01	D. CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10. NO. CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	62777A	3E162777A878		AE		081	
B. CONTRIBUTING							
C. CONTINUING	XXXXXX	STOG 80-7.2.4					
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 012900 Physiology; 013400 Psychology; 022400 Bioengineering; 013300 Protective Equipment; 016200 Stress Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
74 07		CONT		DA		C. IN-HOUSE	
17. CONTRACT GRANT				18. RESOURCES ESTIMATE		19. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PRECEDING		B. FUNDS (in thousands)	
D. NUMBER <sup>a</sup>				FISCAL YEAR		82 1.0 29	
C. TYPE				CURRENT		83 1.0 45	
E. KIND OF AWARD:				F. CUM. AMT.			
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME <sup>a</sup> USA RSCH INST OF ENV MED				NAME <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS <sup>a</sup> NATICK, MA 01760				ADDRESS <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME <sup>a</sup> IRONS, ERNEST M. JR., COL, MSC			
TELEPHONE: 256-4811				TELEPHONE: 256-4811			
21. GENERAL USE				ASSOCIATE INVESTIGATORS			
Foreign Intelligence Not Considered				NAME: VOGEL, JAMES A., Ph.D. POC:DA			
				NAME:			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Military Operations; (U)Performance Limits; (U)Military Tactics; (U)Environmental Medicine							
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Identify environmental medicine problems in Army units as research requirements. Maintain dialogue with DA staff and line to (a) communicate research results to potential users, (b) provide assistance and resolve difficulties in interpreting and applying research, (c) identify unsolved problems. Provide a continuing source of identified, in-depth expertise on the impact of physiological and psychological status; military clothing and equipment; natural and crew compartment environments; high terrestrial elevations; and physical fitness on the soldier's health and mission capability.</p> <p>24. (U) Maintain direct liaison with DA schools, line and staff units by visits, conferences, and correspondence. Maintain reference files on climate, clothing, and equipment, and physical and physiological differences among military populations, as a base for predicting environmental impact and mission capability. Assist in preparation of training films, TB MEDs, FMs, and other doctrine; provide consultation to units planning military operations under stressful conditions; assist with doctrine for physical training and/or acclimatization.</p> <p>25. (U) 81 10 - 82 09 Briefings of military units concerning prophylaxis and therapy for the climatic stress of heat and cold have continued and presentations at civilian institutions have furthered transfer of relevant information between USARIEM and other USAMRDC and DOD biomedical laboratories and civilian organizations involved in common research efforts. Similarly, briefs and consultations with Army Staff e.g., ODCSPER, ODCSOPS and major Army commands, e.g., TRADOC, FORSCOM, REDCOM have provided expertise and recommendations concerning military problems related to environmental stresses, fitness and readiness. In addition, participation in NATO panels has continued.</p>							

<sup>a</sup> Available to contractors upon originator's approval

DD FORM 1498  
MAR 58

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 77, AND 1498B, 1 MAR 58, FOR ARMY USE ARE OBSOLETE.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIAL  
Project: 3E162777A878 Health Hazards of Military Material  
Work Unit: 081 Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination  
Study Title: Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination  
Investigator: Ernest M. Irons, Jr. COL, MSC, Commander/Technical Director, USARIEM

Background:

The research efforts of USARIEM are oriented to improving the capability of US Forces in mission accomplishment. The areas of climatic stress, physiological and psychological stress, physical fitness and ergonomics are the principal research concerns. An important aspect of this effort is the dissemination of current information to the user - the US Forces. The information dissemination takes place in the form of briefings, consultations, scientific papers and technical reports.

To accomplish the information dissemination, efforts are directed toward: 1) predeployment briefings of military units; 2) briefings for major Army Commands and Army Staff (e.g. TRADOC, FORSCOM, HSC, DCSPER, DCSOPS) to provide expertise and recommendations for military problems related to physical fitness, training and readiness; briefings to DoD Offices and activities (e.g. Defense Science Board, AFIRB); 4) consultation with civilian research and academic institutions to transfer relevant and current research data and information.

Progress:

Technology transfer to military users has been effected in a timely fashion. Briefings provided the user with appropriate information with which to assist in the decision making process.

There were 76 consultations requested of the USARIEM Staff from various ACOMS and Army Staff Agencies. Additionally 88 briefings and lectures were given at various locations throughout CONUS and OCONUS. Participation in NATO Panels was continued.

(082)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1 AGENCY ACCESSION*	2 DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD-DR&E(AR)1636	
3 DATE PREV SUMMARY	4 KIND OF SUMMARY	5 SUMMARY SCTY*	6 WORK SECURITY*	7 REGRADING*	8A DISSEM INSTN*	8B SPECIFIC DATA- CONTRACTOR ACCESS	9 LEVEL OF SUM A. WORK UNIT
81 10 01	D.CHANGE	U	U	DA OA 6123	82 09 30	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
10 NO. CODES*	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	62777A	3E162777A878		AE		082	
B. CONTRIBUTING							
C. COORDINATING	STOG 80-7.2.4						
11 TITLE (Precede with Security Classification Code)* (U)Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments (22)							
12 SCIENTIFIC AND TECHNOLOGICAL AREAS* 013300 Protective Equipment; 022400 Bioengineering							
13 START DATE		14 ESTIMATED COMPLETION DATE		15 FUNDING AGENCY		16 PERFORMANCE METHOD	
64 01		CONT		DA		C. IN-HOUSE	
17 CONTRACT GRANT				18 RESOURCES ESTIMATE		A. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PRECEDING		B. FUNDS (in thousands)	
B. NUMBER*				FISCAL YEAR		82	
C. TYPE				CURRENT		10	
D. AMOUNT:				83		10	
E. CUM. AMT.						575	
19 RESPONSIBLE DOD ORGANIZATION				20 PERFORMING ORGANIZATION			
NAME* USA RSCH INST OF ENV MED				NAME* USA RSCH INST OF ENV MED			
ADDRESS* NATICK, MA 01760				ADDRESS* NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME* BRECKENRIDGE, JOHN R.			
TELEPHONE: 256-4811				TELEPHONE: 256-4833			
21 GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: PANDOLF, KENT B., Ph.D. POC:DA			
				NAME:			
22 KEYWORDS (Precede EACH with Security Classification Code) (U)Tolerance Prediction; (U)Protection; (U)Biophysics; (U)Thermal Exchange; (U)Insulation(clo); (U)Evaporative Cooling Index; (U)Moisture Permeability Index							
23 TECHNICAL OBJECTIVE.* 24 APPROACH. 25 PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
23. (U) Study energy exchanges in Man-Clothing-Environment system, to provide basis for improving thermal protection and recommending crew environments in military vehicles.							
24. (U) Analyses of materials, uniforms and/or equipment using heated "sweating" flat plates, manikins, etc. indicate their effects on heat and moisture exchange and aid in predicting the user's physiological responses. Results provide guidance for military designers and identify stressful items or environments. Findings may be verified on soldiers in chamber or field studies.							
25. (U) 81 10 - 82 09 Measurements of the thermal transmission characteristics of various CW-protective clothing systems were continued using the copper manikin and a "sweating" flat plate (for fabric transmission properties); studies were extended to include cold weather ensembles as well as hot weather systems. Manikin studies were also conducted to compare the heat stress of the Temperate Battledress Uniform with that of other hot weather uniforms. Insulation values of a variety of military and commercial sleeping bags were measured before and after laundering, including five candidate bags being considered under the Integrated Fighting System program. Thermal transmission characteristics (clo and $i_m/clo$ ) were established for various items and cold weather aircrew uniform combinations, including three versions of flight coveralls for the Air Force. Measurement of CW-protective clothing systems for carrier operation and analysis of their heat stress potential was performed for the Navy.							

\* Available to contractors upon originator's approval

DD FORM 1498  
MAR 68

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1498B, 1498C, AND 1498D 1 MAR 68 FOR ARMY USE ARE OBSOLETE

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of CW Overgarments with Arctic Ensemble (ME-  
E11-81)  
Investigators: Clement A. Levell and John R. Breckenridge

Background:

While considerable emphasis has been placed on the integration of chemical protection into temperate and hot weather combat uniform systems, little attention has been paid until recently to the problems associated with incorporating such protection into cold weather clothing ensembles. In order to obtain guidance on the thermal exchange effects of utilizing a chemical protective (CW) overgarment in conjunction with an Arctic Ensemble, the Individual Protection Laboratory (IPL), Natick Laboratories, has arranged for copper manikin measurements of thermal insulation and evaporative heat transfer characteristics of several configurations of the standard Arctic ensemble plus CW overgarment. The initial studies were run at a low air movement of 0.3 m/s (chamber conditions) per IPL request.

Progress:

Thermal insulation ( $i_m$ ) and evaporative heat transfer ( $i_m/clo$ ) characteristics have been determined for four configurations of the Arctic ensemble plus CW overgarment. These configurations are as follows:

1. Arctic Ensemble with CW overgarment
2. Arctic Ensemble without Parka and Arctic Trouser liners, with CW overgarment
3. Arctic Ensemble, without Parka and Arctic Trouser liners, with Snow Camouflage Parka and CW overgarment
4. Arctic Ensemble, without Parka and Parka liner, without Arctic Trousers and Trouser liner, with CW overgarment

Similar data were also obtained on the Arctic Ensemble alone; this ensemble included the following items:

Underwear 50/50 wool/cotton  
 Wool shirt  
 Field jacket and trousers with liners  
 Arctic Parka and Arctic trousers with liners  
 Cap, pile  
 White vapor barrier boots with cushion sole socks  
 Arctic mittens with liners and wool mitten inserts

The results of the study are summarized in Table 1.

Table 1  
 Thermal Transfer Characteristics of Arctic/CW Protective  
 Ensembles

	<u>clo</u>	<u><math>i_m</math></u>	<u><math>i_m/clo</math></u>
Arctic Ensemble only	4.69	0.39	0.08
Configuration 1	4.96	0.38	0.08
Configuration 2	4.45	0.40	0.09
Configuration 3	4.66	0.36	0.08
Configuration 4	3.96	0.40	0.10

These results indicate that some reduction in insulation can be obtained (to increase cooling and minimize overheating during sustained activity) by removal of the parka and trouser liners. In fact, removal of these liners compensates for the addition of the CW overgarment quite well; the clo value for configuration 2 is only 0.24 clo less than for the Arctic ensemble alone, and the  $i_m/clo$  is about 12% higher (increased evaporative cooling, if needed). For sustained heavy activity or operation in a moderately-cold environment, the greatest adjustment in heat loss can be made by total removal of the outer layers (parka, trousers and liners), in effect converting to an ensemble of the cold-wet variety (configuration 4). This removal of garments, in the presence of the CW overgarment, provided 0.73 clo less insulation and 0.02 higher  $i_m/clo$  (25% increased potential for evaporative cooling) than the Arctic ensemble alone.

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Cold Weather Aircrew Systems (ME-E10-81)  
Investigator: Clement A. Levell

Background:

The Individual Protection Laboratory (IPL), Natick Laboratories has made arrangements with USARIEM to measure the thermal insulation ( $i_m$ ) and evaporative heat transfer ( $i_m/clo$ ) characteristics of two cold weather aircrewman clothing systems. Essentially, IPL wished to determine the effect of replacing the Parka N3-B with a Jacket N2-B in the cold weather flight ensemble.

Progress:

Copper manikin measurements on the two ensembles have been completed. Ensemble #1 consisted of the following items:

- Wool/cotton underwear
- Coveralls CWU-27P
- Wool/nylon socks
- Leather combat boots
- Trousers, AF cold weather
- Parka N3-B
- Aircrew helmet
- Nomex gloves

Ensemble #2 was the same except that the Jacket N2-B was substituted for the Parka N3-B.

The results of the evaluation are given in Table 1.

TABLE 1  
Insulation (clo) and Evaporative Cooling ( $i_m$ /clo) Coefficients  
for Two Cold Weather Aircrew Ensembles

	clo	$i_m$	$i_m$ /clo
Ensemble #1	3.42	0.42	0.12
Ensemble #2	3.01	0.41	0.14

The difference in insulation (clo) value can be attributed primarily to the difference in area coverage of the Parka N3-B and Jacket N2-B. The N2-B Jacket provides coverage only down to the waist, whereas the Parka N3-B provides coverage down to the mid-thigh. This difference in coverage apparently had little effect on the vapor permeability characteristics ( $i_m$ ) of the system; however, Ensemble 2 with lower clo value has a higher  $i_m$ /clo evaporative cooling coefficient and could dissipate more heat by evaporation of sweat.

Program Element: 6.27.72.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Cold Weather Jacket/Liner Systems Before  
and After Laundering (ME-E22-80)  
Investigator: George F. Fonseca, M.S.

Background:

This sectional manikin study (ME-E22-80) in support of a NLABS project to develop a new jacket liner for cold weather clothing has been completed under Cost Code 9301645000. The experimental procedure followed the design described in the study research plan: manikin evaluations of the jackets/liners systems were done by measuring the effects on  $clo$  and  $i_m$  of replacing the standard liner and jacket worn with a basic cold weather ensemble with each of the experimental liner/experimental jacket combinations. As requested by the Individual Protection Laboratory (IPL), these manikin evaluations of the eight prototype jacket/liner combinations were done before and after three military launderings (cotton wash, tumble dry at  $57^{\circ}C$  ( $135^{\circ}F$ )).

Progress:

The heat transfer properties ( $clo$ ,  $i_m$  and  $i_m/clo$ ) of the standard cold-wet ensemble with the standard jacket and standard liner were determined. This cold-wet ensemble provides the most insulation and the largest impedance to evaporative heat transfer (except for the feet section) over the torso. The insulation over the torso ( $4.9 clo$ ) is about 70% greater than the total insulation ( $2.9 clo$ ) over all six sections of the manikin. The evaporative heat transfer ( $i_m/clo$ ) is 0.08 or 66% of the total  $i_m/clo$ . Considering the manikin area covered by a liner/jacket combination (torso-arms sections), the insulation is  $4.2 clo$  or about 50% greater than the total insulation and the evaporative heat transfer is 0.09 or about 75% of the total  $i_m/clo$ . These heat transfer properties over the torso and arms include the contribution provided by the wool undershirt and wool shirt of the standard cold-wet ensemble.

The insulation (clo) over the torso and arms section per unit weight (kg) of clothing components covering the torso and arms was calculated. These values of insulation as a function of clothing component weight include the contribution of the insulation provided by the external air layer. Wearing a wool undershirt, wool shirt and a liner over the torso provides an average value of about 2.1 clo per kg weight of clothing. The effect on the insulation per kilogram of clothing when a jacket is worn with a liner is to decrease the insulation per kilogram to about 1.3 clo/kg. The standard liner, because of its comparatively light weight, provides the most insulation per kilogram over the torso and arms; 2.6 clo/kg. Although wearing any one of the four jackets over the wool undershirt and wool shirt provides about 3.3 clo of insulation over the torso and arms section, the addition of the Gore-tex jacket provides 1.5 clo/kg compared with 1.2 clo/kg for either experimental jacket.

Considering the insulation provided by all liner/jacket systems prior to laundering shows that the clo values for the torso-arms sections are within  $\pm 5\%$  of 4.4 clo. The standard liner and standard jacket provides 4.2 clo of insulation and the combination with the quilted polyester liner (4.3 clo) provides the lowest insulation and combinations with the unquilted thinsulate liner, unquilted Sontique liner and unquilted thinsulate liner with blue Gore-tex laminated on both sides providing the most insulation; 4.6 clo. The Sontique liner worn with the nylon-cotton field jacket (camouflaged) shows the largest value of  $i_m/\text{clo}$ , 0.10. All liner/jacket combinations are within  $\pm 11\%$  of an  $i_m/\text{clo}$  value of 0.09.

The heat transfer properties over the torso, arms and torso-arms sections after laundering for the prototype liners and jackets substituted for the standard liner and standard jacket were determined. All values of insulation (clo) over the torso-arms section are within  $\pm 7\%$  of an average clo value of 4.3 clo with the combinations with the quilted polyester liner showing the lowest insulation value, 4.3 clo. The most insulation over the torso-arms section is provided by the combination with the unquilted Sontique liner, with an insulation value of 4.8 clo. The combination with the unquilted thinsulate liner with blue Gore-tex laminate on both sides and the Sontique liner with the nylon cotton field jacket (camouflaged) show the largest values of  $i_m/\text{clo}$ , 0.10. The combination with the quilted polyester liner with Gore-tex field jacket shows the lowest value, 0.08. All liner/jacket combinations are within  $\pm 11\%$  of an  $i_m/\text{clo}$  value of 0.09.

A comparison between the heat transfer properties for the torso-arms sections of the manikin covered by these prototype liner/jacket systems before and after laundering indicate little differences between them when these prototype liner/jacket systems are worn as components of a wet-cold ensemble.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Three CVC Helmet Systems (ME-E18-80)  
Investigator: George F. Fonseca, M.S.

Background:

This study was initiated at the request of the Individual Protection Laboratory (IPL) at the Natick Research and Development Laboratories (NLABS) to evaluate three prototype suspension systems in an experimental Combat Vehicle Crewman (CVC) helmet. Any given suspension system modifies the evaporative heat transfer properties of a helmet, in part, by the total head-suspension system contact area, the distribution of this contact area over the head and the material composition and thickness of the suspension system.

Progress:

Three prototype suspension systems were received, the last one on 1 Mar 82, and evaluated using just the head section of the sectional heated manikin. These evaluations were made in conjunction with an on-going chamber study.

The Table shows the heat transfer properties ( $clo$ ,  $i_m$  and  $i_m/clo$ ) of the three prototype suspension systems in an experimental Combat Vehicle Crewman (CVC) helmet. The evaporative heat transfer from the head, based on these  $i_m/clo$  values for a vapor pressure difference between a completely wet (maximal sweating) head surface and ambient air with 15 mm Hg vapor pressure (as for 85°F, 50% relative humidity), is: 10 watts for DH 140, 8 watts for DH 132 and 17 watts for prototype #1. This comparison shows that prototype #1 allows about twice the evaporative cooling as either DH 140 or DH 132.

The surface area affected by a helmet is relatively small (about 0.14 m<sup>2</sup>) compared with the total body surface area (about 1.8 m<sup>2</sup>). Thus, any

improvement in the heat transfer properties of headgear is more apt to be reflected in increased head comfort rather than in any meaningful extension of physiological tolerance. This study on the evaluation of three CVC helmet systems is completed.

TABLE  
HEAT TRANSFER PROPERTIES OF 3 IPL PROTOTYPE CVC HELMET  
SUSPENSION SYSTEMS (ME-E18-80)

Headgear	Clo	$I_m$	$I_m/Clo$
CVC Helmet w/suspension:			
DH 132	1.50	0.33	0.22
DH 140	1.59	0.29	0.18
Prototype #1	1.12	0.41	0.37

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Extreme Cold Sleeping Bags (ME-E18-81)  
Investigators: John Fiumara and Clement A. Levell

Background:

The Individual Protection Laboratory (IPL), Natick Laboratories has arranged with USARIEM to perform copper manikin insulation measurements on four types of experimental extreme cold weather sleeping bags as well as the standard issue. Measurements were to be made (1) on one of each type in a new condition; (2) on one of each type new, after one laundering, and after three launderings; and (3) on two of each new and after three launderings. These multiple measurements were reportedly requested to permit IPL to identify the best experimental bag design, insulationwise, and consider its suitability as a replacement for their current standard bag.

Progress:

Insulation (clo) values of the various bags were measured on a supine copper manikin in the Arctic Conditioning Chamber; all bags were measured on the UK foam pad (the so-called US current standard item) and results include its thermal protection. Results of the determinations are given in Table 1.

The various bags were not identified as to design, filling material, etc., nor was the letter designation for the standard bag indicated by IPL. Accordingly, the results were reported to IPL with little comment, except about the magnitudes of insulation decrements, graded by identifying letter, after the IPL laundering process.

TABLE 1  
Insulation (clo) Values for Four Experimental and Standard  
Types of Extreme Cold Sleeping Bags (Including UK Foam Pad)

Bag (Type and Number)	New	After One Laundering	After Three Laundering
A-1	6.32	6.23	5.88
A-2	6.57		6.02
A-3	6.21		5.92
A-4	7.18		
B-1	7.04	6.99	6.70
B-2	7.21		6.64
B-3	6.86		6.28
B-4	6.53		
C-1	7.05	6.93	6.86
C-2	6.94		6.77
C-3	6.22		6.19
C-4	6.33		
D-1	7.77	7.63	7.35
D-2	7.57		7.07
D-3	7.56		Not laundered
D-4	7.28		
E-1	7.67	7.37	7.13
E-2	7.18		6.91
E-3	7.20		7.10
E-4	7.16		

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards Of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Extreme Cold Weather Flying Gloves (ME-E1-  
82)  
Investigator: Thomas L. Endrusick

Background:

The Individual Protection Laboratory (IPL), Natick Laboratories has developed an experimental Extreme Cold Weather Flying Glove with integral insulating lining. This glove was being considered as a possible replacement for the two-piece glove system consisting of the HAU-6/P leather glove and standard five-finger wool insert. IPL therefore requested that insulation data be obtained on the two systems, and on a system consisting of HAU-6/P glove, wool insert and rayon Anti-Contact Insert so that they might assess the adequacy of the experimental item. The three systems were accordingly measured on the USARIEM sectional copper hand under a reimbursement contract with Natick Laboratories.

Progress:

Copper hand measurements indicated an overall insulation value of 1.37 clo for the Experimental Extreme Cold Weather Flying Glove, compared with 1.31 clo for the HAU-6/P leather glove and five-finger wool insert, and 1.41 clo for the HAU-6/P glove, wool insert and rayon anti-contact insert. The measured insulation provided the individual finger sections by the experimental item was equal to or slightly higher than provided by the multi-layer systems in almost every instance, indicating that the experimental item would be a satisfactory substitute, protection-wise, for the HAU-6/P five-finger insert combination.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Insulation Values of Commercial Sleeping Bags (ME-E3-82)  
Investigators: John R. Breckenridge and John Fiumara

Background:

Individual Protection Laboratory (IPL), Natick Laboratories is evaluating various off-the-shelf items for potential military use, and is stressing in particular its study of commercial extreme cold sleeping bags. The thermal insulation properties of seven such bags have been determined for IPL under a reimbursement contract, using a supine copper manikin. Measurements were made with the bag resting on the United Kingdom foam pad.

Progress:

Insulation values (clo) have been obtained for each bag (plus pad) before and after a series of launderings. Results are given in Table 1.

TABLE 1  
Insulation Values of Commercial Sleeping Bags  
(clo units)

Bag Number	Before Laundering	After Laundering
1	6.19	Not Laundered
2	6.11	6.37
3	6.13	6.16
4	6.50	6.50
5	6.17	6.10
6	6.50	6.50
7	6.06	6.44

All of these bags would provide approximately the same protection for the sleeping soldier, and would permit six hours restful sleep at temperatures down to about  $-10^{\circ}\text{C}$ . Laundering had only slight effect on insulation value in most cases; however, the clo values of bags 2 and 7 increased noticeably, presumably because the laundering process increased the loft of the bag filling material.

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of ILC Dover Camouflage CW Overgarment in  
Wind (ME-E4-82)  
Investigator: Clement A. Levell

Background:

In support of its program to develop new chemical protective clothing for the Army, the Individual Protection Laboratory (IPL), Natick Laboratories has constructed a new overgarment consisting of a five-layer Gore-tex, charcoal impregnated foam laminate plus a camouflage-print water repellent outer shell. This prototype is presumably intended as a battledress uniform with integrated CW protection. The Gore-tex in the laminate is included to prevent sweat uptake by the foam, yet permit free transfer of evaporated sweat. IPL has requested a copper manikin evaluation of the heat and vapor transfer characteristics of this prototype, at low air movement and in a 5 mph wind, to permit comparison of its heat stress potential relative to that of the standard CW overgarment and other experimental designs which have been previously evaluated.

Progress:

The ILC Dover overgarment was evaluated without fatigues in a closed configuration (with M-17 mask, hood and gloves) using the "sweating" copper manikin. Insulation value (clo), and evaporative cooling coefficient are given in Table 1 for air movements of 0.3 m/s ("still" air) and 2.23 m/s (5 mph) wind. Comparable data for the standard overgarments, with and without camouflage cover (obtained earlier under our study ME-E20-81, reported in Annual Progress Report, FY 81) are included in Table 1 for comparison.

TABLE 1  
Wind Effects on Thermal (clo) and Evaporative Exchange  
( $i_m/clo$ ) Characteristics of ILC Dover Camouflage CW  
Overgarment ("Closed" Configurations)

Wind Speed	ILC Dover Overgarment		Standard Overgarment		Camouflage-print Overgarment	
	clo	$i_m/clo$	clo	$i_m/clo$	clo	$i_m/clo$
"still"	1.97	0.18	2.16	0.11	2.27	0.12
5 mph	1.38	0.28	1.38	0.31	1.43	0.32

These results indicated that the ILC Dover overgarment has an advantage relative to reduced heat stress in low air movement (lower clo value combined with higher evaporative cooling coefficient  $i_m/clo$ ) but that this advantage virtually disappears in a 5 mph wind. The standard and camouflage overgarments are readily penetrated by wind, resulting in insulation (clo) reductions at 5 mph of 36% and 37%, and increases in  $i_m/clo$  of 181% and 167%, respectively. However, because of the virtually windproof Gore-tex layer in the ILC Dover overgarment, internal convection in a wind is minimized and a 5 mph wind reduces clo value by only 30%; more importantly, the wind increases  $i_m/clo$  and evaporative cooling potential by only 55%, thus nullifying the advantage in "still" air of the ILC Dover system ( $i_m/clo$  was 50% higher than for the standard overgarments). Based on previous experience, higher winds would cause more pronounced changes in the standard overgarment parameters than in those of the Gore-tex lined item, causing this item to show a disadvantage, insofar as heat stress is concerned, at winds much above 5 mph. These results confirm the previous observation that use of an air (but not vapor) impermeable layer in a CW ensemble should be avoided in the interests of reducing heat stress, since such a layer reduces beneficial changes in thermal exchange characteristics, not only in wind but also as a result of body motion during periods of activity when need for cooling is the greatest.

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIAL  
Project: 3E162777A878 Health Hazards of Military Material  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Insulative Values of Military Sleeping Bags (ME-E5-82)  
Investigator: Thomas L. Endrusick

Background:

Numerous copper manikin evaluations of thermal insulation are performed by USARIEM for Individual Protection Laboratory (IPL), Natick Laboratories, in support of their program to develop or procure commercial extreme cold sleeping bags with improved thermal protection capabilities. The present study, one of four during FY 82, involved measurement of three different commercial bags being considered for procurement for the Marine Corps to determine which would have the best insulation characteristics.

Progress:

Thermal insulation (clo) values of each bag, measured in combination with a United Kingdom foam underpad, were determined on a supine manikin in accordance with standard procedures. The values before and after several launderings are given in Table 1.

TABLE 1  
Insulation Values of Candidate Marine Corps Bags

Bag Marking	Before Laundering (clo)	After Laundering (clo)
MC 1	6.55	6.55
MC 2	6.32	6.10
MC 3	7.58	6.58

The insulation values for bags MC 1 and MC 2 before laundering are approximately the same as for the Army standard extreme cold bag, and would protect down to the same temperature as the Army bag (plus UK pad); about six hours of restful sleep could be obtained at  $-15^{\circ}\text{C}$ . Bag MC 3 before laundering would permit a  $7^{\circ}\text{C}$  lower temperature (1 clo higher insulation value). However, the laundering process lowered the insulation value of this bag by 1.0 clo so that, after laundering, all bags provided approximately equal protection. The laundering effects on bags MC 1 and MC 2 were typical of those usually observed, i.e., laundering usually changes insulation by up to 0.3 clo. No explanation could be provided IPL for the abnormal laundering effect on bag MC 3.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Cold Weather Aircrew Clothing Systems (ME-E6-82  
Amended)  
Investigator: George F. Fonseca, M.S.

Background:

In support of an NLABS project (Project Order No. Natick 82-150) to develop a new cold weather aircrew clothing system, a sectional manikin study was initiated to determine the heat transfer properties ( $\text{clo}$ ,  $i_m$  and  $i_m/\text{clo}$ ) of prototype aircrew cold weather clothing ensembles designated for DT/OTI tests.

Progress:

Table 1 gives the sectional and total values of the insulation ( $\text{clo}$ ) and evaporative heat transfer ( $i_m/\text{clo}$ ) obtained with Jackets N-2B and N-3B dressed on the sectional manikin over standard cold weather aircrew clothing. This study is continuing an evaluation of a series of prototype cold weather aircrew ensembles.

TABLE 1

## COLD WEATHER AIRCREW CLOTHING SYSTEM (ME-E6-82 Amended)

SECTIONS	W/Jacket N-2B			w/Jacket N-3B		
	CLO	$I_m$	$I_m/CLO$	CLO	$I_m$	$I_m/CLO$
Torso	4.52	0.36	0.08	5.09	0.39	0.08
Arms	3.73	0.48	0.13	3.91	0.44	0.11
Legs	3.87	0.49	0.13	4.43	0.50	0.11
Head	1.94	0.42	0.22	2.03	0.43	0.21
Hands	1.28	0.41	0.32	1.52	0.50	0.33
Feet	1.57	0.23	0.15	1.55	0.18	0.11
T-A	4.21	0.41	0.10	4.61	0.41	0.09
T-A-L	4.05	0.45	0.11	4.52	0.45	0.10
Total	3.00	0.39	0.13	3.29	0.41	0.13

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Evaluation of Sleeping Bags for High Technology Test Bed  
(ME-E8-82)  
Investigators: Thomas L. Endrusick and John R. Breckenridge

Background:

An Integrated Infantry Fighting System Joint Working Group (JWG) has been tasked by the Army to formulate a more efficient cold weather clothing/protection system for infantry personnel, in coordination with the High Technology Test Bed (HTTB), 9th Infantry Division, Seattle, WA. Five candidate clothing systems, comprising military or commercially available items, have been specified and will be field-tested by HTTB during January 1983. Other personal protection items, including five commercial sleeping bags, will also be evaluated during the field exercise. USARIEM has agreed to support this study by providing insulation data on the clothing systems and sleeping bags, in order that an initial screening may be made prior to their usage in the field.

Progress:

Insulation values of five commercial sleeping bags intended for the HTTB program have been measured using a supine copper manikin. The descriptions and insulation values (clo) for these bags are given in Table 1.

The results were transmitted to the 9th ID Project Officer for HTTB through Individual Protection Laboratory (IPL), Natick Laboratories; a simple interpretation of the implications of insulation (clo) differences and changes with laundering was provided for HTTB guidance.

TABLE I  
Insulation (clo) Values of HTTB Sleeping Bags

Mfr	Model	Bag No.	Fill	Clo (unlaundered)	Clo (laundered)
Slumberjack	President 4	H1	64 oz Hollofil II	7.26	6.91
Northface	Bigfoot	H2	Polargard	6.46	5.97
Early Winters	Silver Lining	H3	45 oz Polyester	6.47	6.21
Wilderness Experience	Latok I	H4	80 oz Polyester	6.95	6.50
Cold River	78223R	H5	48 oz Hollofil II	5.25	5.34

Program Element: 6.27.77A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design including the Selection of Crew Compartment  
Environments  
Study Title: Biophysical Evaluation of Soviet Winter Gloves (FOM-2-  
8415-6-12) (ME-E10-82)  
Investigator: Thomas L. Endrusick

Background:

An evaluation of the insulating characteristics of a Soviet winter glove obtained in Afghanistan and forwarded to Natick Laboratories through intelligence channels has been requested by the Individual Protection Laboratory (IPL). The glove was of a two-finger variety constructed of canvas and coarse felt materials.

Progress:

The insulation value of the Soviet glove was measured on the USARIEM copper hand with the first two fingers separately inserted into the mitten finger pockets. The overall insulation was 1.77 clo, almost identical to that for the US Army standard three-finger wool mitten (1.76 clo). IPL was also provided a section-by-section comparison of the insulation distribution in the two items; although some local differences were observed, the fingers in both items provided similar protection, on average.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Biophysical Assessment of CW Fabrics and Uniforms (ME-  
E13-82)  
Investigators: John R. Breckenridge and Clement A. Levell

Background:

The Individual Protection Laboratory (IPL), Natick Laboratories is involved in a continuing program to develop chemical protective ensembles for the individual soldier. Numerous approaches aimed at reducing the potential for heat stress in these ensembles are being investigated, including the use of thinner, less insulative, absorptive layers, designs to enhance water vapor transfer and cooling by sweat evaporation, etc.. USARIEM is assisting in this program by evaluating the thermal exchange characteristics of new CW protective composites and uniform items as they are developed. Initial assessment of the merits of a system is made on flat samples using a "sweating" guard ring flat plate to measure insulation (clo) value and evaporative heat transfer coefficient ( $i_m/clo$ ). This approach permits layer systems showing little promise of providing reduced heat stress to be discarded or modified before being incorporated into actual clothing. Considerable time and expense in development of CW items with promising thermal characteristics is eliminated by this screening process, allowing designers to direct their efforts to best advantage.

Progress:

Thermal exchange characteristics of 14 candidate CW fabric combinations have been measured on the USARIEM "sweating" guarded flat plate. Information collected included the insulating value (clo), moisture permeability index ( $i_m$ ), and the evaporative heat transfer coefficient ( $i_m/clo$ ). The results are summarized in Table 1.

TABLE I  
Thermal Exchange Characteristics of 14 Candidate CW-Protective  
Layer Systems

	Fabric System	<u>clo</u>	<u>i<sub>m</sub></u>	<u>i<sub>m</sub>/clo</u>
1.	Polyethylene Oxide (90 mil treated foam)/NYCO OG outer shell	1.31	0.55	0.42
2.	Storm Shed/90 mil foam (standard)	0.95	0.26	0.27
3.	NYCO OG (5.5 oz)/90 mil foam (standard)	0.99	0.46	0.46
4.	NYCO Camouflage (6.8 oz)/90 mil foam (standard)	1.00	0.47	0.47
5.	BDO/3M Laminate	0.71	0.43	0.61
6.	Storm Shed/50 mil foam	0.75	0.23	0.31
7.	Nylon K-Cote (FR)/90 mil foam (standard)	0.99	0.11	0.11
8.	Nylon K-Cote (FR)/50 mil foam (laminated)	0.82	0.09	0.11
9.	100% Ctn Ripstop (FR) (WR)/90 mil foam (standard)	1.06	0.46	0.43
10.	Gore-tex camouflage cloth laminate/90 mil foam (standard)	0.99	0.33	0.33
11.	NYCO OG (5.5 oz)/charcoal cloth	0.89	0.41	0.46
12.	Nylon K-Cote (FR) alone	0.53	0.06	0.12
13.	NYCO camouflage (5.5 oz)/Gore-tex laminate "B", 6.1 oz Nexus	0.85	0.44	0.52
14.	NYCO camouflage (5.5 oz)/Gore-tex laminate "D", 7.2 oz Kynol	0.96	0.51	0.53

The analysis of results which was provided IPL pointed out that, based on the evaporative coefficient,  $i_m/clo$ , the BDO/3M laminate ( $i_m/clo = 0.61$ ) showed the most promise of minimizing thermal stress in hot environments. The least promising systems, i.e., those with lowest  $i_m/clo$ , were those which included a moderately vapor-resistant Storm Shed layer (systems 2 and 6) or a practically impermeable K-cote layer (systems 7 and 8). Systems with a permeability index ( $i_m$ ) greater than 0.40 (1, 3, 4, 5, 9, 11, 13 and 14) were all considered to have

excellent evaporative transfer characteristics. System I had a noticeably higher  $i_m$  value than the rest, but this advantage is not considered real since a one-piece sample could not be obtained for measurement; the sample, which had to be taped together, did not lie flat on the plate, resulting in abnormally high  $clo$  and  $i_m$  values for the sample.

Program Element: 6.27.77.A HEALTH HAZARDS OF MILITARY MATERIEL  
Project: 3E162777A878 Health Hazards of Military Materiel  
Work Unit: 082 Biomedical Impact of Military Clothing and Equipment  
Design Including the Selection of Crew Compartment  
Environments  
Study Title: Biophysical Comparisons of Battle Dress and Other Hot  
Weather Uniforms (ME-E14-82)  
Investigators: John R. Breckenridge and Thomas L. Endrusick

Background:

Numerous reports have been received from the field that the recently introduced Temperate Battle Dress Uniform feels hotter and imposes more heat stress than standard tropical and desert uniforms issued to Army personnel. To check on the validity of these reports, and locate the cause of the increased stress, if any, Individual Protection Laboratory (IPL) has arranged with USARIEM for (1) biophysical measurement of the thermal exchange characteristics of the fabrics used in standard temperate, tropic and desert uniforms, and (2) copper manikin assessments of the thermal and evaporative exchange parameters of the uniforms themselves. At the same time, IPL arranged for a human study of the uniforms, which is reported elsewhere (Physiological Evaluation of the Temperate Battle Dress Uniform, ME-2-82, under DA OB 6148). Measurement of the insulation (clo) and evaporative heat transfer coefficient ( $i_m/clo$ ) for the fabrics was carried out using a "sweating" guarded hot plate, while those on the uniforms were performed on a standing "sweating" manikin in a tropical chamber with a wind speed of 3 mph (1.3 m/s).

Progress:

The results of evaluations of the five fabrics used in standard hot weather uniforms (including the tropical camouflage fabric used in Marine Corps uniforms) are given in Table 1.

All of the fabrics had practically the same total insulation value (including external air layer), indicating that the insulation value per se is not responsible

for any reported differences in thermal stress. The moisture permeability index ( $i_m$ ) and ratio  $i_m/clo$  for all of the fabrics are also quite similar, although it can be seen that the Temperate BDU and Desert BDU fabrics have index values which are a few percent below those for the Tropical and Durable Press Utility Uniform fabrics. In particular, the  $i/clo$  ratios, which determine resistance to evaporative cooling, are from 6 to 8 percent lower for the Temperate and Desert BDU fabrics than for the Tropical and Durable Press Uniform fabrics. In a given hot environment, this difference would suggest that, at the least, 6-8% more of a man's skin would have to be sweat-wetted in the Temperate BDU Uniform than in either Tropical Uniform to obtain the same amount of evaporative cooling. This difference could conceivably cause a noticeable increase in thermal discomfort (with the Temperate Uniform); these findings are not definitive owing to the uncertainty of extrapolating from fabric values to the actual thermal exchange characteristics of the uniform itself.

TABLE I

Insulation (clo) and Moisture Permeability ( $i_m$ ) Values  
of the Uniform Materials as Measured on a Heated, Sweating Flat Plate

<u>Uniform</u>	<u>Insulation</u> (clo)	<u>Moisture Permeability</u> ( $i_m$ )	<u>Index Ratio</u> ( $i_m/clo$ )
Temperate BDU			
Woodland	0.60	0.55	0.92
Desert BDU			
Camouflage	0.58	0.50	0.86
(Rerun)	0.58	0.53	0.91
Tropical Combat			
Camouflage	0.58	0.57	0.98
OG-107	0.58	0.56	0.97
Durable Press Utility			
OG-507	0.55	0.56	1.02

The results obtained in the Tropical Chamber (air temperature 30°C, 75% relative humidity, wind speed 3 mph) are summarized in Table II.

TABLE II

Thermal Exchange Parameters of Hot Weather Uniforms

	clo	$i_m$	$i_m/\text{clo}$
Temperate BDU	1.29	0.61	0.47
Desert BDU (Camouflage)	1.28	0.60	0.47
Tropical Combat (Camouflage)	1.19	0.51	0.43
Tropical Combat (OG-107)	1.35	0.58	0.43
Durable Press Utility (OG-107)	1.20	0.51	0.42

According to these results, the Temperate and Desert Battle Dress Uniforms would cause less thermal stress than the Tropical or Durable Press Uniforms, since they show a higher evaporative cooling coefficient ( $i_m/\text{clo}$ ). This finding is in conflict with the results for the fabrics, but it cannot be simply ascertained whether the discrepancy is real or the result of experimental inaccuracies. Multiple repeat measurements on the uniforms would have provided clarification but could not be pursued due to time and manpower restraints.

1498

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 121 Prophylaxis Susceptibility and Predisposing Factors of  
Cold Injury  
Study Title: Thermographic Evaluation of Experimentally Produced Cold  
Injury of Rabbit Feet  
Investigators: John A. Kelly, MAJ, VC, D.V.M. and Murray P. Hamlet,  
D.V.M.

Background:

Previous research conducted on the thermographic evaluation of experimentally produced frostbite utilized the production of a fourth degree necrotizing lesion (Hamlet, et al., 1977).

In that study, the patterns of skin temperatures, as measured by thermography, enabled the prediction of a line of demarcation and extent of subsequent sloughing early in the course of frostbite injury. After four hours, the thermographs of the individual rabbit paws showed marked temperature gradients and by 24 hours the thermographic patterns were well defined and clearly depicted the tissue that would slough. Although the main arterial blood supply was still demarcated, there were parallel isotherms running from the lateral border to the medial border at the freeze line. In that study, points on the bottom of each foot were chosen for statistical analysis of temperature differences at each time post-thaw. The points were chosen to reflect the areas of major blood supply proximal and distal to the freeze line. The use of these points to represent the entire area of the extremity is limiting; therefore, a technique for measuring the total surface area, at any predetermined time using a 10°C range, was developed utilizing the video disk memory and thermovision software system. The purpose of this research is to determine the value of thermographs as a prognostic tool in differentiating degrees and extent of tissue damage using the technique for measuring total surface area.

### Progress:

Thirty-six rabbits have been induced with cold injury and the data from these rabbits has been digitized and stored in the computer. The temperatures used for the induction of cold injury were between  $+10^{\circ}\text{C}$  and  $-20^{\circ}\text{C}$ . Two major problems encountered with the analysis and correlation of this data are as follows:

(1) Determining the exact proximal edge of the foot for each thermograph taken. This problem is created because it is difficult to get the same angle of the foot and camera each time a thermograph is taken.

(2) Determining the exact distal edge of healthy tissue when there is tissue loss. The isotherms are not always parallel and it is difficult to determine the size of the scar tissue. We hope to eliminate these problems as soon as the Oscar (off-line system for computer access & recording) which we have on hand is interfaced to the computer.

The following observations have been made from the analysis of this group of rabbits:

(1) If the internal temperature of the foot did not go below  $0^{\circ}\text{C}$  within 20 minutes then there was no or little tissue loss. Actually there was a net average gain of approximately 1.603 cn which was due to swelling from the injury.

(2) If the internal temperature went below  $0^{\circ}\text{C}$  and the time was longer than 20 minutes then there was tissue loss. The amount of loss in most cases was dependent on time of exposure.

(3) Average area lost for foot temperature between  $-1^{\circ}\text{C}$  to  $-10^{\circ}\text{C}$  was approximately 8.903 cn with an original area average of 20.078 cn.

(4) Average area lost for foot temperature between  $-10^{\circ}\text{C}$  to  $-22.9^{\circ}\text{C}$  was approximately 11.386 cn with an original area average of 19.656 cn.

### LITERATURE CITED

Hamlet, M., S. Veghte, W. Bowers and S. Boyce. Thermographic evaluation of experimentally produced frostbite of rabbit feet. *Cryobiology* 14:197-204, 1977.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 121 Prophylaxia Susceptibility and Predisposing Factors of  
Cold Injury  
Study Title: Sympathetic Dopaminergic Mediation of Cold-Induced  
Vasodilation  
Investigator: Carl A. Ohata, CPT, MSC, Ph.D.

Background:

The underlying neuronal mechanisms mediating cold-induced vasodilation remain unknown. Previous studies in this laboratory have shown that the efferent sympathetic nerves, not the parasympathetic nerves (vagus nerve and sacral ventral roots), may affect cold-induced vasodilation (Ohata, 1982). Bilateral sectioning of the lumbar sympathetic nerves produced a large peripheral hyperemia, warming of the footpad, and increased heat loss from the footpad. It appears that sympathetic denervation interrupted the normally high  $\alpha$ -adrenergic vasoconstrictor tone which is elicited during cold exposure. This intense peripheral vasoconstriction is normally inhibited centrally by the baroreceptors during cold-induced pressor responses resulting in a reflex peripheral vasodilation, i.e. "cold-induced vasodilation."

Active vasodilation has also been observed in which peripheral vasodilation occurs without a concomitant pressor response. Previous studies have shown that active vasodilation may occur by sympathetic  $\beta$ -adrenergic, histaminergic, or cholinergic mechanisms, but these mechanisms allow a selective redistribution of blood flow to primarily skeletal muscle. In contrast, sympathetic dopaminergic vasodilation occurs primarily in the vasculature of the skin. This vasodilation occurs by activation of specific dopamine receptors (Bell & Stubbs, 1978) which are located in the arterio-venous anastomoses of the canine footpad (Bell et al., 1978) by electrical stimulation of the efferent lumbar sympathetic chain (Buylaert et al., 1977). The preferential redistribution of blood flow to the skin elicited by sympathetic efferent release of dopamine causing dopaminergic receptors in arterio-venous anastomoses to open may be important in mediating cold-induced vasodilation. The object of this study is to determine if cold-induced vasodilation in the cat is mediated by dopamine, if sympathetic efferent fibers elicit the vasodilation, and if the vasodilation is modulated by carotid baroreceptors.

### Progress:

Experiments are presently being performed on cats anesthetized with chloralose (50 mg/kg i.v.). The cats were pretreated with guanethidine (5 mg/kg) 48, 24 and 2 hours before the experiment in order to deplete norepinephrine in postganglionic sympathetic adrenergic nerves which, in effect, eliminates complications arising from sympathetic vasoconstrictor fibers. A snare is looped around each common carotid artery to subsequently elicit the baroreceptor reflex by tightening the snare. A femoral vein is cannulated to infuse drugs and for fluid replacement with lactated Ringer's solution. In the hindlimb being studied for cold-induced vasodilation, an electromagnetic flow probe is attached to the femoral artery for the monitoring of peripheral blood flow, and the temperature and heat loss of the footpad is monitored. Other parameters monitored are mean arterial blood pressure, heart rate, rectal temperature, ambient temperature and expiratory  $\text{CO}_2$ .

In preliminary findings, dopamine (0.01 and 0.1  $\mu\text{g/kg}$  i.v.) produced a dose-dependent hyperemia, warming and increased heat loss from the footpad, and an unexpected pressor response of 5 to 10 minutes duration. These responses were obtained when the foot was exposed to room air and after 90 minutes immersion in a cold bath. These responses were attenuated by ergonovine maleate (25  $\mu\text{g/kg}$  i.v.), a dopamine receptor antagonist, suggesting that specific dopamine receptors in the hindlimb mediated the peripheral vasodilation. The dosage to elicit the vasodilation in cats is 1/50 that used in the dog to elicit a response of similar magnitude indicating a much greater sensitivity of dopamine receptors in the cat. Another species difference is that there is a dose-dependent pressor response in the cat which is absent in the dog. This pressor response is mediated by dopamine activation of  $\alpha$ -adrenergic receptors because the pressor response can be blocked by phentolamine (0.5 mg/kg i.v.), an  $\alpha$ -adrenergic receptor antagonist, but is not blocked by propranolol (0.1 mg/kg i.v.), a  $\beta$ -adrenergic receptor antagonist. Following larger doses of dopamine (0.04, 0.4, 4 mg/kg i.v.), there was peripheral vasoconstriction and an even larger pressor response suggesting that large doses of dopamine activate  $\alpha$ -adrenergic vasoconstrictor receptors which override the vasodilator responses due to activation of dopamine receptors by smaller dosages of dopamine. Bilateral common carotid occlusion was always ineffective in producing the reflex vasodilation observed in previous studies. This suggests that the baroreflex

vasodilation is mediated by an inhibition of sympathetic noradrenergic vasoconstrictor tone. In this study, pretreatment of the cats with guanethidine depletes norepinephrine and therefore blocks the sympathetic vasoconstriction which is a prerequisite for the baroreceptor-mediated vasodilation.

#### LITERATURE CITED

1. Bell, C., W.J. Lang and F. Laska. Dopamine-containing axons supplying the arterio-venous anastomoses of the canine paw pad. *J. Neurochem.* 31:1329-1333, 1978.
2. Bell, C. and A. Stubbs. Localization of vasodilator dopamine receptors in the canine hindlimb. *Br. J. Pharmac.* 64:253-257, 1978.
3. Buylaert, W.A., J.L. Willems and M.G. Bogaert. Vasodilation produced by apomorphine in the hindleg of the dog. *J. Pharmacol. Exp. Ther.* 201:738-746, 1977.
4. Ohata, C.A. Effects of autonomic denervation on cold-induced vasodilation in the hindlimb of the anesthetized cat. *Fed. Proc.* 41(5):1486, 1982.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 121 Prophylaxia Susceptibility and Predisposing Factors of  
Cold Injury  
Study Title: Neural Influences in Cold-Induced Vasodilation  
Investigator: Carl A. Ohata, CPT, MSC, Ph.D.

Background:

Cold-induced vasodilation, a warming of peripheral tissues during prolonged exposure to cold, protects these tissues from cold injury. It appears that cold-induced vasodilation is reflexly elicited by baroreceptors in response to cold-induced pressor responses. Baroreceptors are located in the heart, aorta and carotid sinuses with afferent fibers in the stellate ganglia and upper thoracic sympathetic rami communicantes, the vagus nerves including the aortic depressor nerve, and the carotid sinus nerves. The object of this study is to determine the effects on cold-induced vasodilation of sequentially denervating the afferent baroreceptor nerves bilaterally. The effects of baroreceptor deafferentations on the carotid sinus baroreceptor reflex was also determined since the carotid baroreflex elicits marked cardiovascular and thermal responses similar to that in cold-induced vasodilation.

Progress:

Experiments were performed on cats anesthetized with chloralose (50 mg/kg i.v.). A femoral vein was cannulated for fluid replacement. An endotracheal tube was inserted and breathing was assisted with a respirator. In the hindlimb being studied for cold-induced vasodilation, an electromagnetic flow probe was attached to the femoral artery, and the temperature and heat loss from the footpad was monitored. Other parameters monitored were mean arterial blood pressure, heart rate, rectal temperature, ambient temperature, and expiratory  $\text{CO}_2$ ; thermal insulation of the footpad and femoral arterial resistance were calculated.

Baroreceptors are widely distributed in large vasculature with afferent fibers in a variety of nerves. Baroreceptor deafferentation involved sequential bilateral denervations of the stellate ganglia including the ansa subclavia, cervical sympathetic chain and  $S_{1-4}$  rami communicantes to eliminate sympathetic afferents (S1), aortic arch denervations and vagotomy (S2), and carotid sinus denervations (SC). The carotid baroreceptor reflex was elicited by tightening a snare around both common carotid arteries.

Cardiovascular and thermal responses were monitored for an hour when the foot was in room air (A), after immersion of the foot in a cold bath (B), after baroreceptor deafferentations, and during exposure to room air after the denervations (R). Heart rate was highest during the room air control period, lowest after stellectomy, and at intermediate but declining levels for all other phases. Blood pressure was highest in the neurally-intact foot immersion period but lower and indistinguishable among the other phases (Fig. 1). Vascular resistance was lowest in the room air control, higher after foot immersion, still higher after stellectomy and vagotomy, highest after carotid denervation, and still high after exposure to room air; this resulted in an inverse relationship in femoral blood flow (Fig. 1). The footpad was warm when not immersed and cooled progressively after the denervations (Fig. 1). Heat loss from the footpad was higher after immersion but diminished to lower levels when blood flow was attenuated after the denervations.

The effect of baroreceptor deafferentations on carotid baroreflexes produced the greatest insight into baroreceptor regulation of cold-induced vasodilation. Bilateral common carotid occlusion produced an immediate tachycardia, pressor response, and vasoconstriction during the first minute of occlusion; these responses were attenuated by successive denervations. Secondary vasodilation occurred after the initial vasoconstriction. This vasodilation was largest in the neurally-intact immersion period (B), and was attenuated by sequential denervations indicating that cardiac and aortic baroreceptors principally mediate the vasodilation. It appears that these baroreceptors respond to the initial pressor response elicited by carotid occlusion resulting in a secondary peripheral vasodilation. The increase in peripheral blood flow, skin temperature and heat flow to carotid occlusion were largest in the neurally-intact immersion, stellectomy, and vagotomy phases.

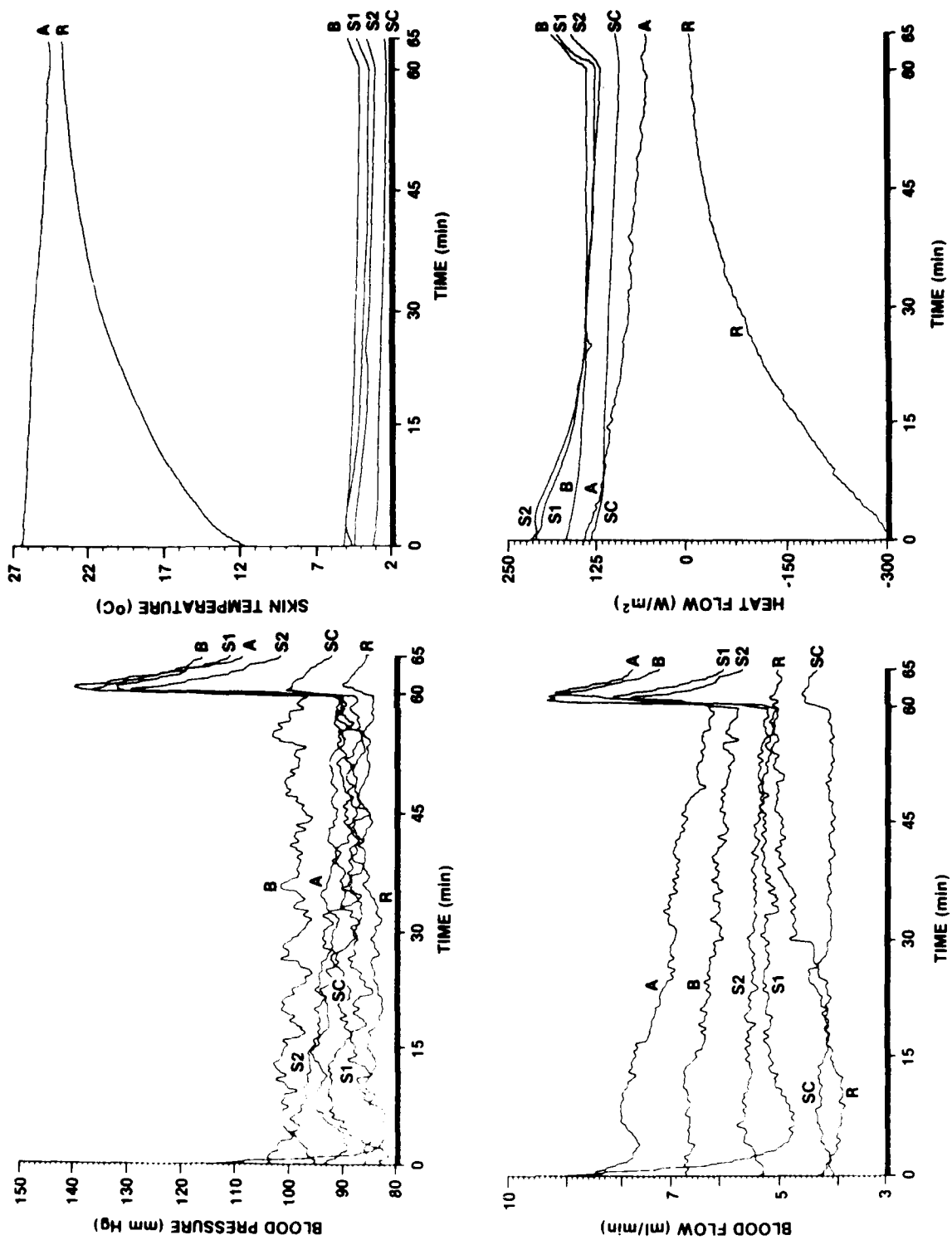


Figure 1. Effects of re-setting carotid sinus pressure on femoral arterial vasculature resistance, femoral arterial blood flow, temperature of the footpad, and heat loss from the hindlimb in cats with the hindlimb exposed to cold (a) and after immersion in a cold bath (b).

In summary, it appears that cold-induced vasodilation is mediated primarily by cardiac and aortic baroreceptors with sympathetic and vagal afferents. The vasodilation and peripheral warming is a secondary response to an initial pressor response elicited by carotid occlusion.

Presentation:

Ohata, C.A. Effects of autonomic denervation on cold-induced vasodilation in the hindlimb of the anesthetized cat. Federation of American Society for Experimental Biology. New Orleans, April 1982. Fed. Proc 41:1486, 1982.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 121 Prophylaxia Susceptibility and Predisposing Factors of  
Cold Injury  
Study Title: Role of Carotid Baroreceptors in Influencing Cold-Induced  
Vasodilation  
Investigator: Carl A. Ohata, CPT, MSC, Ph.D.

Background:

There is evidence that cold-induced vasodilation occurs during pressor responses. This suggests that the baroreceptors sensing different levels of systemic blood pressure are simultaneously eliciting reflex changes in peripheral blood flow, surface temperature and heat loss from the footpad of cats. The purpose of this study is to determine if re-setting the baroreceptor responsiveness in isolated carotid sinuses can elicit reflex cardiovascular and thermal responses in the unimmersed and cold-immersed hindlimb, similar to that observed during cold-induced vasodilation.

Progress:

Experiments were performed on cats anesthetized with chloralose (50 mg/kg i.v.). A femoral vein was cannulated for fluid replacement. An endotracheal tube was inserted and breathing was assisted with a respirator. In the hindlimb being studied for cold-induced vasodilation, an electromagnetic flow probe was attached to the femoral artery, and the temperature and heat loss from the footpad was monitored. Other parameters monitored were mean arterial blood pressure, heart rate, rectal temperature, ambient temperature, expiratory CO<sub>2</sub> and carotid sinus blood pressure.

A carotid sinus was vascularly isolated to regulate its internal pressure. A roller pump connected to the common carotid artery regulated the inflow of blood. The outflow of blood was regulated by clamping a cannula shunting blood from the external carotid artery to the jugular vein. All collateral arteries were ligated to prevent leakage of blood from the isolated sinus. The cat was heparinized to prevent the formation of thromboses. In order to study the

baroreceptor reflexes from only the isolated carotid sinus, the influence of other baroreceptor nerves was eliminated by sectioning the vagus nerves and denervating the contralateral carotid sinus.

A stimulus-response relationship to increasing carotid sinus pressure at 95 mm Hg steps from 50 to 250 mm Hg was obtained when the hindlimb was in room air and 90 minutes after immersion in a cold bath (Fig. 1). The classical sigmoidal relationship of tachycardia at low carotid pressure and bradycardia at high carotid pressure was obtained when the foot was in room air; there was no relationship between heart rate and carotid pressure when the foot was immersed in a cold bath. The heart rate response was due to variations in cardiac sympathetic tone since the vagus nerves were cut. The unusual cardiac response during foot immersion was attributed to somatosympathetic reflexes overriding the carotid baroreceptor reflex. Blood pressure varied inversely to carotid pressure in both room and cold-immersed conditions. However, this trend was arbitrary from the expected sigmoidal relationship since the mean blood pressures monitored over 15 minutes included cardiovascular adjustments which attenuated the momentary baroreceptor reflexes elicited immediately after a change in carotid pressure. Femoral arterial vascular resistance was directly related to carotid pressure (Fig. 1). The reflex vasodilation at low carotid pressure allowed an increase in femoral blood flow, and vice versa at higher carotid pressures. These trends were similar in both room and cold-exposed conditions, but the greater vascular resistance and lower blood flows during cold exposure indicates a relatively higher level of vasoconstriction in the cold hindlimb. With increased blood flow at low carotid pressures, there was a warming of the footpad and increased heat loss, and conversely at higher carotid pressures (Fig. 1).

In summary, the effect of varying carotid sinus pressure can reflexly affect the peripheral cardiovascular and thermal responses similar to that observed in cold-induced vasodilation. There was evidence that complex cardiovascular reflexes, especially baroreceptors from sites other than the carotid sinus, may modify the carotid baroreflexes during prolonged monitoring.

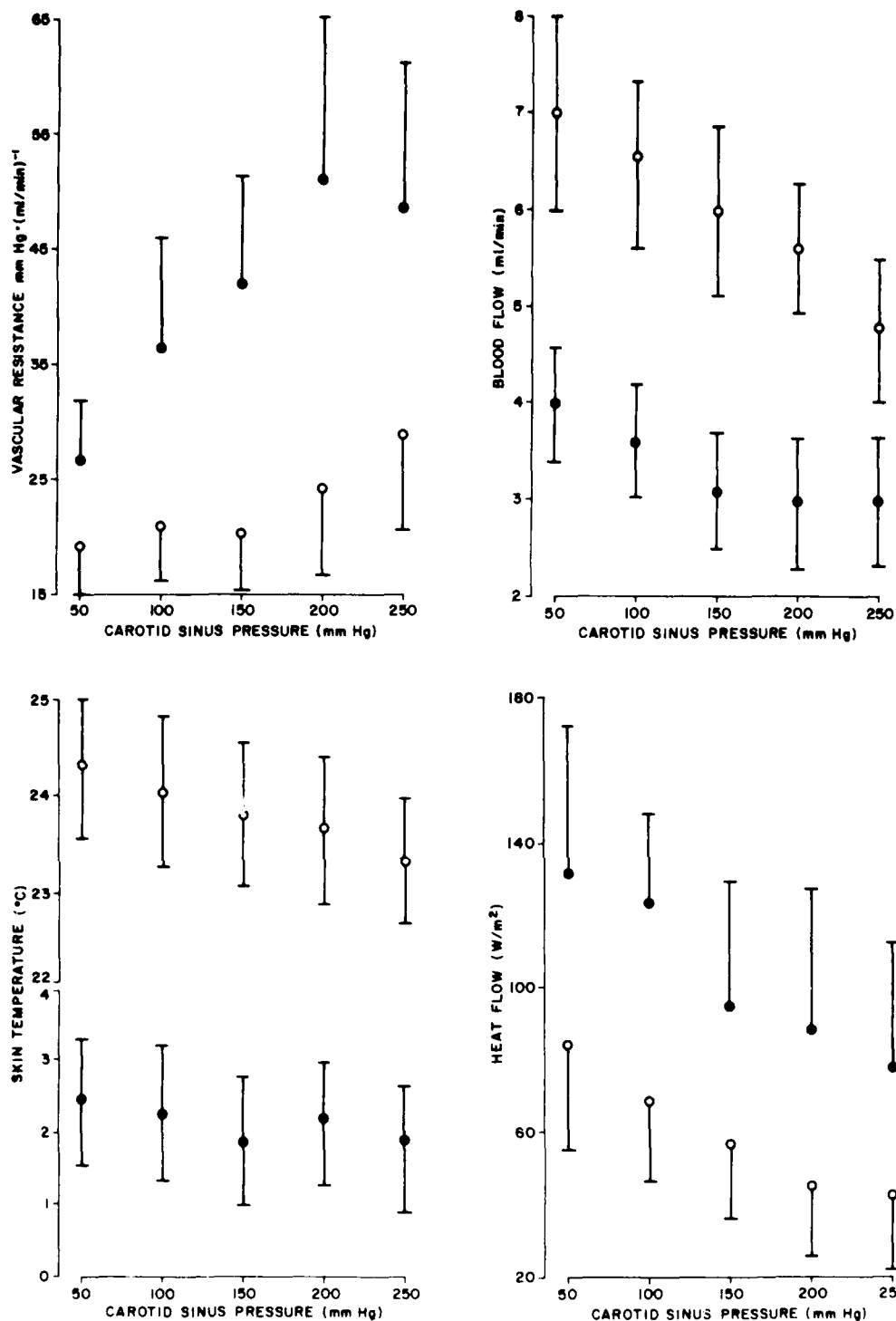


Figure 1. Effects of re-setting carotid sinus pressure on femoral arterial vasculature resistance, femoral arterial blood flow, temperature of the footpad, and heat loss from the footpad in cats with the hindlimb exposed to room air (o) and after immersion in a cold bath (●).

FOR REVIEW

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY						1. AGENCY ACCESSION #		2. DATE OF SUMMARY	
3. DATE PREVIOUS SUMMARY						DA OB 6144		82 09 15	
4. KIND OF SUMMARY		5. SUMMARY SCOPE		6. WORK SECURITY		7. REL. INSTR.		8. OR DISB. INSTR.	
82 04 35		D. CHANGE		U		U		NL	
10. NO. LINES		PROGRAM ELEMENT		PROJECT NUMBER		TASK AREA NUMBER		WORK AREA	
A. PRIMARY		62777A		3E162777A879		BA		12	
B. CONTRIBUTING									
C. <del>XXXXXX</del>		STAG 80-7.2:4							
11. TITLE (Precede with Security Classification Code)									
(U) Models of Heat Disabilities: Treatment and Diagnosis (22)									
12. SCIENTIFIC AND TECHNOLOGICAL AREAS									
005900 Environmental Biology; 003500 Clinical Medicine									
13. START DATE			14. ESTIMATED COMPLETION DATE			15. FUNDING AGENCY		16. FUNDING ELEMENT	
76 10			CONT			DA		CIN	
17. CONTRACT / GRANT					18. RESOURCES ESTIMATE		19. PROFESSIONAL PERSONNEL		
A. DATES / EFFECT DATE					PRECEDING				
B. NUMBER					FISCAL YEAR				
C. TYPE					82				
D. KIND OF AWARD					83				
E. AMOUNT									
F. CUM. AMT.									
20. RESPONSIBLE DOD ORGANIZATION					20. PERFORMING ORGANIZATION				
NAME					NAME				
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ADDRESS					ADDRESS				
NATICK, MA 01760					NATICK, MA 01760				
RESPONSIBLE INDIVIDUAL					PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. citizen)				
NAME IRONS, ERNEST M. JR., COL, MSC					NAME MAGER, MILTON, Ph.D.				
TELEPHONE 256-4811					TELEPHONE 256-4871				
21. GENERAL USE					ASSOCIATE INVESTIGATORS				
Foreign Intelligence Not Considered					NAME HUBBARD, ROGER, Ph.D.				
					NAME FRANCESCONI, RALPH P. Ph.D.				
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Disabilities; (U)Military Heat Stress; (U)Pathology; (U)Physiology; (U)Biochemistry; (U)Behavior; (U)Tolerance; (U)Heat; (U)Human Voluntary									
23. TECHNICAL OBJECTIVE 24. APPROACH 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code)									
<p>23.(U) The use of model systems to develop newer methods of treatments or diagnosis of heat-related injuries and performance decrements associated with military operations in the heat.</p> <p>24.(U) Various agents will be tested for their efficacy in reducing core temperature, reducing the pathological effects of hyperthermia, increasing performance, or alleviating the symptomatology of heat illness among humans or animals acutely exposed to high environmental temperatures or of work regimens. A variety of clinical and physiological parameters will be evaluated for their usefulness in the diagnosis of heat illness, and to characterize the response of humans those who have experienced or are susceptible to heat related injury.</p> <p>25.(U) 81-89 - 82-89 Guidelines for prevention of heat casualties were developed and tested during large scale tactical maneuvers under hot-dry and hot-wet conditions and found to be meeting operational and physiological requirements. This doctrine (DA Cir. 40 82 3) requires monitoring of environmental conditions with a simple, small device (Batsball) and limiting individual water intake from 0.5 qt/hr during mild heat conditions to 2.0 qt/hr during extreme conditions. Simultaneous alterations in work-rest cycles from 50/10 min to 20/20 min maintained temperatures near normal. Commanders can thus operate in extreme environments at a slower rate, and complete missions without undue performance decrements. Currently, high volunteers are being tested to evaluate the enhancement of water acceptance in hot wet environments. During the course of a six hour exposure, subjects walk on a treadmill at a 5% grade for 30 min each hr at a rate of 3 mph. The walk simulates a 9 mile hike and a very mild heat 2000 ft. Conditions are temperature 104°F, relative humidity 32% and wind speed 10 mph. Various combinations of factors, such as chlorine (5 ppm) or iodine (16 ppm) concentration, water temperature (114°F or 60°F) and flavoring agents on voluntary water consumption are being evaluated. The results will provide new insights into preventing voluntary dehydration and heat illness.</p>									

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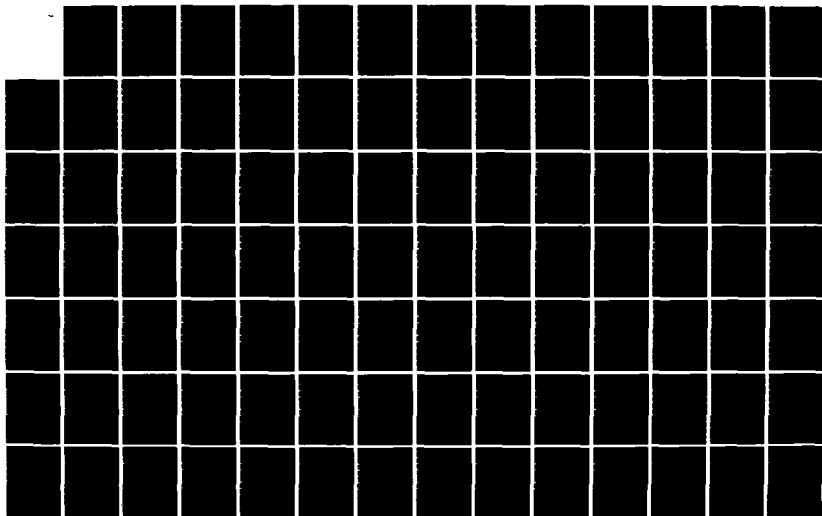
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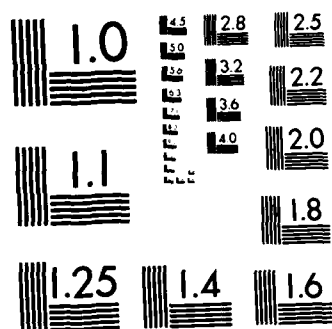
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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 122 Models of Heat Disabilities: Treatment and Diagnosis  
Study Title: Effects of Water Temperature and Flavor in the  
Development of Voluntary Dehydration  
Investigators: Milton Mager, Ph.D., Roger W. Hubbard, Ph.D. and Ralph P.  
Francesconi, Ph.D.

Background:

Ordinarily, the dynamic balance between fluid ingestion and output is maintained in equilibrium by fluid consumption and water loss via respiration, urination, and perspiration. However, early work demonstrated that during work in the heat humans rarely voluntarily drink as much water as they lose and usually replace acutely approximately 70% of the net water loss. Under conditions of prolonged heat exposure, this pattern will elicit progressive dehydration, steadily rising core temperature, elevated pulse rates, and declining sweat rates, all with an increased potential for heat injury. Rothstein and his associates observed the same phenomenon along men working in the desert and called the process voluntary dehydration. Adolph characterized some of the factors involved in the intensity of voluntary dehydration, and identified ambient temperature, metabolic load, temperature and accessibility of water, time available for drinking, and potability as factors affecting the degree of voluntary dehydration.

In military scenarios drinking by command, as practiced by the Israelis, has reduced casualty rates in both hot-dry and hot-wet environments. The Israelis have found that a cold (10-13°C), sweetened, fruit-flavored drink readily available throughout the day provided optimal rehydration. Unfortunately, these criteria are not easily achieved under field conditions on the desert especially when disinfecting agents, such as chlorine or iodine, must be added to the water. This experiment will be designed to quantitate the extent of voluntary dehydration during a prolonged walk under desert conditions when warm or warm-iodinated tap water is available for drinking. Additionally, the effects of cooling and/or flavoring the drinks during the experimental interval will be determined.

### Progress:

Adult, male volunteers will be recruited from the local test subject population, and anthropometric data will be collected. The testing will be carried out in a large climatic chamber facility with an air temperature of 40°C d.b./26°C w.b., rh = 32%, and wind speed of 2.5 mph. Each subject will spend 6h in the chamber on each of 2 non-consecutive days. During each h Ss will march for 30 min at 1.34m/sec at a 5% grade and rest for 30 min. Thus, over 6 h they will cover 14.5 Km and simulate a climb of 724 m. During both the exercising and sedentary periods, Ss will have ad lib access to either tap water, tap water treated with iodine tablets (8 mg/l), or tap water treated with iodine and flavored with a commercially available cherry-flavored beverage powder. On one test day each group will receive their appropriate beverage at a temperature of 40°C and during the second session the same drink will be cooled to 15°C. Body weights will be closely monitored at the beginning and end of each exercise period and rectal and skin temperatures and electrocardiograms will be continually observed.

The word alliesthesia has been used to describe the pleasure or displeasure associated with a stimulus that can induce a pleasant or unpleasant sensation depending upon the intensity of the stimulus and the internal state of the subject. For example, a cold stimulus would be pleasurable during hyperthermia but unpleasant during hypothermia. Thus, the positive alliesthesia for cold fluid can result from hyperthermia rather than dehydration since subjects who will consume warm fluids over the 6 h period may be more dehydrated during the warm-fluid trial yet consume less due to non-palatability factors. Further our data should indicate whether flavoring agents or disinfectants can enhance either positive or negative water alliesthesia, respectively. These studies may provide important information on the effects of flavoring agents and water temperature on the development of voluntary dehydration. The results of these experiments will be useful in developing requirements for field water supplies (e.g. temperature, chillers, flavorings) to assure maximum fluid consumption during military operations in jungle and desert environments.

FOR REVIEW

(123)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD FORM 1498, 1 MAR 68	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM
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10. NO. CODES*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER			
a. PRIMARY	62777A	3E162777A879	BF	123			
b. CONTRIBUTING							
c. CONTRIBUTING	STOG 80-7.2.4						
11. TITLE (Precede with Security Classification Code)*							
(U) Physical Fitness Requirements, Evaluation and Job Performance in the Army (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS*							
012900 Physiology; 012500 Personnel Training & Evaluation							
13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD				
76 10	CONT	DA	C. IN HOUSE				
17. CONTRACT GRANT		18. RESOURCES ESTIMATE	19. PROFESSIONAL MAN YRS	20. FUNDS (in thousands)			
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NATICK, MA 01760		NATICK, MA 01760					
RESPONSIBLE INDIVIDUAL		PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)					
NAME: IRONS, ERNEST M. JR., COL, MSC		NAME: VOGEL, JAMES A., Ph.D.					
TELEPHONE: 256-4811		TELEPHONE: 256-4800					
21. GENERAL USE		ASSOCIATE INVESTIGATORS					
Foreign Intelligence Not Considered		NAME: PATTON, JOHN, Ph.D. POC:DA					
		NAME: WRIGHT, JAMES, CPT., MSC, Ph.D.					
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Physical Fitness; (U)Muscle Strength; (U)Aerobic Fitness; (U)Fitness Evaluation; (U)Job Performance; (U)Physical Training; (U)Job Tasks; (U)Human Volunteer.							
23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Physical fitness training programs and standards should be based on the minimum requirements commensurate with good health, appearance and MOS performance plus the added requirements of unit and mission performance. Research is needed to objectively link and translate these requirements into appropriate levels of physical fitness that can be applied to the soldier.</p> <p>24. (U) Specific areas of study will include: (1) physiological demands of MOS tasks, (2) added fitness requirements for sustained operations, sleep loss and confinement, (3) development of improved body weight (obesity) standards (4) development of improved fitness screening and testing procedures and (5) physiological factors influencing lifting ability and lifting task performance.</p> <p>25. (U) 81 10 - 82 09 (1) An operational test and evaluation of the USARIEM recommended fitness test battery for use at the Military Enlistment Processing Stations was initiated during this period. The battery, to be used for MOS qualification, will be evaluated against successful MOS performance. (2) A maximal predictive cycle ergometer test has been developed and evaluated in conjunction with other NATO countries. The test, which requires exercise to maximal exertion but without measurement of oxygen uptake, is superior to the standard Astrand test. (3) A study has been conducted to evaluate the Army two mile run test for aerobic fitness against maximal oxygen uptake. Preliminary results show an excellent relationship across a wide age and fitness span.</p>							

\*Available to contractors upon originator's approval

DD FORM 1498

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 123 Physical Fitness Requirements, Evaluation and Job  
Performance in the Army  
Study Title: Relationship Between the Army Two Mile Run Test and  
Maximal Oxygen Uptake  
Investigators: Robert P. Mello, M.S. and James A. Vogel, Ph.D.

Background:

The US Army recently selected the two mile run for time as its main test of aerobic fitness. The basis for this decision is the generally held belief that a run of one to two miles (five to fifteen minutes) correlates reasonably well with a person's aerobic fitness as determined by maximal oxygen uptake ( $\dot{V}O_2$  max). A review of the literature does identify some studies comparing  $\dot{V}O_2$  max with a variety of run tests, most often twelve or fifteen minute runs for distance (1,2) or a one or 1 1/2 mile run for time (4,5), but few actual direct comparisons of the two mile run with  $\dot{V}O_2$  max.

The purpose of this study was to examine the relationship between maximal oxygen uptake and the Army's two mile run for time. A sizable data base would be established from which the important aspects of gender, age, and relative fitness levels could be observed.

Additional impetus for this study recently came from the Army's Office of Deputy Chief of Staff for Operations which is currently proposing a system of periodically assessing the aerobic fitness of the Army by random sampling of subpopulations with the timed two mile run test. These samples, in turn, would be further verified by  $\dot{V}O_2$  max measurements in small subsamples. Such an approach would require a well-documented, statistically valid relationship between the two measures.

Progress:

A group of sixty volunteer test subjects (45 military, 15 civilian), both male (n=44) and female (n=16) ranging in age from eighteen to fifty-one

participated in this study. All subjects were asked to perform two basic tests within fifteen days of each other: a timed two mile run test on a measured level asphalt surface; and a treadmill determination of maximal aerobic capacity ( $\dot{V}O_2$  max) using the Douglas bag technique (3). Both the treadmill and two mile run tests were performed in PT clothes and running shoes; and all subjects were urged to provide a maximal effort in performing both tests to the best of their individual abilities. Additional measurements made on each subject included: height, weight, and body fat assessment by the skinfold caliper technique.

The majority of subjects participating in this study (75%) were part of the permanently assigned military personnel of USARIEM. As such, these subjects were required to participate in the biannual Army Physical Readiness Test (APRT), which includes pushups, situps, and a timed two mile run. Table 1 defines the relationship between age, aerobic fitness level ( $\dot{V}O_2$  max) and two mile run time.

TABLE 1

Comparison of Age,  $\dot{V}O_2$  max, and Run time

Age	n	$\dot{V}O_2$ max	2-Mile Time
20-24	18	49.8 $\pm$ 6.9	15:12 $\pm$ 2:11
25-29	15	48.2 $\pm$ 7.0	15:17 $\pm$ 2:42
30-34	16	48.8 $\pm$ 10.9*	15:22 $\pm$ 3:20
35-39	6	46.7 $\pm$ 6.2	15:36 $\pm$ 1:39
over 40	5	44.5 $\pm$ 3.9	15:37 $\pm$ 1:06

\*Four Marathon Runners in this Group.

Table 1 illustrates the typical response one would expect with an increase in age, i.e., a slight decline in  $\dot{V}O_2$  max and a corresponding increase in two mile run times.

Table 2 describes the relationship between gender and relative fitness levels ( $\dot{V}O_2$  max and 2 mile time).

TABLE 2

Gender,  $\dot{V}O_2$  max, and 2-Mile Run time

Gender	n	$\dot{V}O_2$ max	2-mile time
Male	44	50.4 $\pm$ 7.8	14:43 $\pm$ 2:07
Female	16	42.6 $\pm$ 5.6	17:07 $\pm$ 2:48

It is apparent from Table 2 that the  $\dot{V}O_2$  max values and two mile run times for males were significantly better than those of their female counterparts. This occurred in spite of the fact that more than half of the females tested (9 of 16) were active joggers (three or more times weekly/two or more miles per session).

Analysis of data collected to this point describes an excellent relationship between  $\dot{V}O_2$  max and two mile run time. The coefficient of correlation for all subjects (male and female) was  $r = -0.91$ . Separate regression analysis for both male and female data also display excellent correlation.

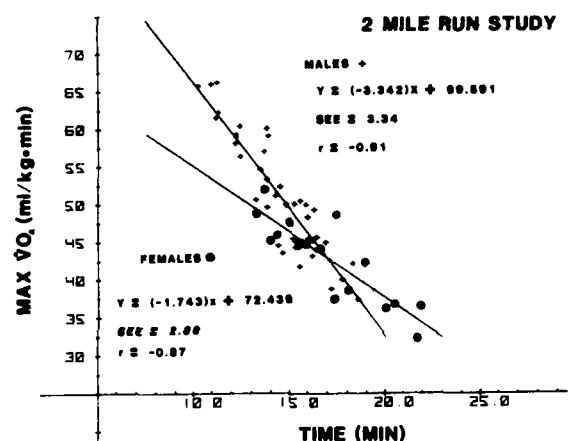


Figure 1:  $r$  (males) = -0.91,  $r$  (females) = -0.87).

Analysis of the above data demonstrates the strong relationship that exists between a person's aerobic fitness level ( $\dot{V}O_2$  max) and his/her two mile run time. It is therefore reasonable to conclude that prudent application of the predictive properties of this simple relationship ( $\dot{V}O_2$  max to 2-mile run time) could prove very useful to the US Army. It must be re-emphasized, however, that the timed two mile test must be run to the best of one's personal abilities for this relationship to hold true.

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5. Cooper, K.H. *The New Aerobics.* Bantom Books, New York, 1970.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 123 Physical Fitness Requirements, Evaluation and Job  
Performance in the Army  
Study Title: Operational Test of a Gender-free Physical Capacity Test  
Battery  
Investigators: James A. Vogel, Ph.D., James E. Wright, CPT, MSC, Ph.D.,  
Marilyn A. Teves, M.S. and Patricia I. Fitzgerald, CPT,  
MSC, Ph.D.

Background:

In 1977, USARIEM was tasked to establish gender-free physical fitness standards for Military Occupational Specialty (MOS) qualification as well as a fitness test battery to screen applicants for these standards. This work was completed and reported (1-4). Because of the projected impact of implementing such a system, further action was postponed. Continued pressure, however, from the Secretary of the Army initiated new interest in MOS fitness standards in the spring of 1981. This led, in part, to the formation of the Women in the Army Study Group. This Group re-did our task analysis and MOS clustering and re-established MOS standards. To complete the action, ODCSPER tasked us on 15 July 1982 "to develop and validate a gender-free military enlisted physical strength capacity test battery (MEPSCAT)." This study represents our response to this tasking.

Progress:

The operational test was designed to comparatively evaluate five proposed test items for the fitness battery. The selection of these five items was based on our previous work (3,4). They included:

1. Step test or Astrand cycle test
2. Body composition by skin fold caliper
3. 38 cm isometric upright pull force
4. Handgrip force
5. Maximal dynamic incremental lift

The study, beginning on 8 September, includes three phases:

1. Pre-initial entry training
2. Post-initial entry training
3. Post-advanced individual training

A total of 2000 recruits are being evaluated in the test, equally divided between males and females. A sample of 20 percent of the original number will be retested in phase 2 (post - IET) and the entire sample will be re-evaluated.

Phase 1 will consist only of the administration of the five item test battery. Phase 2 will consist of the five item battery plus two criterion capacity measures:

1. Maximum safe lift capacity to 132 cm
2. Maximal exercise cycle performance

Phase 3 will consist of the five item battery plus the performance of a selection of criterion performance tasks. A set of tasks to represent each MOS cluster will be developed and administered as criteria for evaluating the efficacy of the test battery items.

In addition, throughout the study, additional military performance criteria will be collected to include:

1. Physical readiness test scores
2. Attrition, discharge
3. Recycle actions
4. Injury incidence

Phase 1 was initiated on 8 September. Phase 2 will commence on 17 November and Phase 3 on 1 December. Expected completion is in April 1983.

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4. Letter report to HQDA, ATTN: DAPE-MPE, Subject: Final Report - Gender-Free Fitness Test. 26 September 1980.

FOR REVIEW

(124)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD-DR&E-AR 16 16	
				DA OB 6142	82 09 30		
3. DATE PREV SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8. DISEN INSTR <sup>a</sup>	9. SPECIFIC DATA - CONTRACTOR ACCESS <input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
82 04 30	D.CHANGE	U	U		NL		
10. NO. CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
a. PRIMARY	62777A	3E162777A879		BB		124	
b. CONTRIBUTING							
c. <del>XXXXXX</del>	STOG 80-7.2:4						
11. TITLE (Precede with Security Classification Code) <sup>a</sup>							
(U) Treatment of Cold Injury (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 002300 Biochemistry; 002600 Biology; 012900 Physiology; 005400 Environmental Biology; 003500 Clinical Medicine							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
76 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING			
b. NUMBER:				FISCAL		2.0	
c. TYPE:				YEAR		56	
d. KIND OF AWARD:				CUM. AMT.		2.5	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup>				NAME: <sup>a</sup>			
USA RSCH INST OF ENV MED				USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup>				ADDRESS: <sup>a</sup>			
NATICK, MA 01760				NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Inst.)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> HAMLET, MURRAY P., D.V.M.			
TELEPHONE: 256-4811				TELEPHONE: 256-4865			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: KELLY, JOHN, MAJ, VC, D.V.M.			
				NAME: POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Hypothermia; (U)Blood Coagulation; (U)Vasodilation; (U)Angiography; (U)Laboratory Animal.							
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Although cold injury is of little clinical significance in the civilian community, it has had serious impact on every Army that has attempted to fight in the cold. Hospitalization times for cold-induced injuries during the Korean and Second World War were 37 and 57 days respectively. Amputation and permanent loss of function and death are routine sequelae. Current knowledge suggests that increased blood flow and internal methods of rewarming, and surgical approaches to frostbite may decrease the hospitalization time and increase tissue salvage.</p> <p>24. (U) An intravenous frostbite treatment solution was developed and utilized during the Korean conflict. Animal studies will be done with modifications of this formula to include more effective vasodilators to determine the effect on long-term tissue survival. Internal methods of rewarming hypothermic animals will be studied for the effects on those physiologic parameters that affect survival. Studies on blood coagulation, fibrinolysis, and platelet aggregation after frostbite will be done.</p> <p>25. (U) 81 10 - 82 09 In severe frostbite there is a decrease in erythrocyte count, hematocrit, albumin, and prothrombin time and an increase in leukocyte count, plasma hemoglobin, fibrinogen, antithrombin III activity, partial thromboplastin time, and clotting Factors II, VII, IX, X activities. Results indicate altered liver production and no disseminated intravascular coagulation. In mild frostbite, similar changes occur except in lower change in albumin and clotting factor activities. It is felt that plasma changes will not assess severity of frostbite injury. DMSO-treated frozen rabbit ears lost less tissue than saline treated ears and prophylactically treated ears froze slower than saline controls. Thirty animals have been completed on the intravenous frostbite treated solution protocol but data analysis is incomplete.</p>							

<sup>a</sup>Available to contractors upon originator's approval

DD FORM 1498

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 124 Treatment of Cold Injury  
Study Title: Evaluation of Therapeutic Intravenous Frostbite Solution  
Investigators: John A. Kelly, MAJ, VC, D.V.M. and Murray P. Hamlet,  
D.V.M.

Background:

An intravenous frostbite solution was described in a report of the cold injury research team Medical Research and Development Board, Office of The Surgeon General, Department of the Army (20 March 1951) (1). The mission of this team was to study the various types of cold injury occurring in the Korean theater of operations and to report the procedures found most effective in evaluation, treatment and rehabilitation of cold injury casualties. On the team's visit to the Cold Injury Treatment Center, (21 Feb 51-28 Feb 51), they discovered that an intravenous frostbite solution was recommended as part of the treatment prior to and after arrival at the treatment center. Later the use of this solution was put in a command directive dealing with cold injury problems in Korea. The formula and its recommended administration were as follows for 2nd and 3rd degree involvement:

12cc ethyl alcohol  
250 mg procaine hydrochloride  
5% glucose in water to make 250 cc

1. For frostbite
2. Dosage; contents of this flask (250cc), repeated every six hours for several days.
3. Instructions:
  - a. Start as early as possible after each diagnosis.
  - b. For frostbite cases without other wounds 100 mg heparin will be added to each 250cc of solution prior to the administration (2).
4. Caution:
  - a. Use only the 23-gauge needle provided with the set.
  - b. In doubtful cases, heparin will be used only at the discretion of the local medical officer.

There is nothing in the literature on how this formula was derived, nor its actual results as a treatment. Work at this laboratory and elsewhere indicates that there are two major injuries associated with frostbite (3,4). The first is the physical effect of the ice crystal formation within the tissue and the second is a microvascular stasis that occurs within a short time after the thawing procedure (3,5,6,7,8). The subsequent cessation of nutritive flow contributes substantially to the overall destructive process of frostbite necrosis (9). It is suspected that the therapeutic value of this solution lies within the vasodilatory property of alcohol and procaine and the anticoagulant effect of the heparin promoting microcirculation. This study will be undertaken to see what degree of therapeutic results can be achieved with this solution.

#### Progress:

Thirty control rabbits have been induced with cold injury and the data from these rabbits has been digitized and stored in the computer. The preliminary results so far are comparable to those of study "Thermographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet." As soon as the Oscar (off line system for computer, access and recording) which we have on hand is interfaced to the computer we will complete this study using the intravenous frostbite solution. This equipment will give us a closer delineation of healthy and injured tissue from the thermographs as opposed to the video disk system we are presently using.

#### LITERATURE CITED

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 124 Treatment of Cold Injury  
Study Title: The Alteration in Blood Coagulation, Fibrinolysis and  
Platelet Aggregation in Mild and Severe Frostbite  
Investigator: John Gadarowski, CPT, MSC, Ph.D.

Background:

Few studies have been reported dealing with measuring changes in blood coagulation, fibrinolysis, or platelet aggregation in frostbite injury. Lepp et al. (1) measured a prolonged prothrombin time in rats exposed to subfreezing air. Barkagan and Plotnikov (2) studied 260 patients with acute frostbite injury. They found an increase in platelet aggregation and an activation of the intrinsic and extrinsic blood coagulation pathways. Chohan et al. (3) studied 15 human high altitude cases at 24 hours, 4 weeks, and 1 year after injury. Reduction in platelet count, antithrombin III activity, and plasma fibrinogen and an increase in fibrin degradation products showed that intravascular coagulation was occurring at 4 weeks after injury. However, Quintanilla et al. (4) found that prolonged administration of heparin to frostbitten rabbits did not significantly improve their pathology as compared to nonheparinized frostbitten rabbits.

The purpose of this study was to evaluate in rabbits the severity of the frostbite injury to the degree of systemic plasma changes in plasma coagulation, fibrinolysis, and platelet aggregation. One of the difficulties in the treatment of frostbite is the lack of a method of determining immediately the degree of frostbite injury so that appropriate treatment could be started. It was hoped that these changes in the plasma could determine the degree of frostbite injury.

Progress:

The experiments have been completed. The data is presently being presented for publication. A summary of the study is as follows. Acute systemic blood changes were measured in New Zealand white rabbits after severe and mild frostbite injury to the foot. There was observed after 72 hours in the severely

frostbitten rabbits a decrease in erythrocytes, hematocrit, lymphocytes, and albumin and an increase in total leukocytes, neutrophils, platelets, fibrinogen, and antithrombin-III. Mild frostbitten rabbits showed similar changes except for no changes in the platelets, albumin, and antithrombin-III. In severely frostbitten rabbits after 72 hours the changes in the plasma coagulation tests were a prolonged partial thromboplastin time, an accelerated prothrombin time and increased activities of Factors VII, IX, X, and XI. In mild frostbitten rabbits there was a prolonged partial thromboplastin time and an increased activity of Factor VII. No changes in fibrinolysis were seen in either group of rabbits. Platelet aggregation, studied only in the severely frostbitten rabbits, showed a change only by an increase in the slope of the collagen induced platelet aggregation. The blood changes observed in the rabbit model are different than that reported in human frostbite cases. No disseminated intravascular coagulation was apparent in the rabbit model after frostbite injury.

#### LITERATURE CITED

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FOR REVIEW

(125)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION <sup>a</sup>	2. DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL DD DR&E-AR 1636	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY <sup>a</sup>	6. WORK SECURITY <sup>a</sup>	7. REGRADING <sup>a</sup>	8A. DISB'N INSTR'N	8B. SPECIFIC DATA - CONTRACTOR ACCESS	9. LEVEL OF SUM A. WORK UNIT
82 04 30	D. CHANGE	U	U	DA OB 6147	NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
10. NO./CODES: <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER		WORK UNIT NUMBER		
a. PRIMARY	62777A	3E162777A879	BF		125		
b. CONTRIBUTING							
c. CONTROLLING	STOG 80-7.2.4						
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Physical Fitness Training and Prevention of Injuries Related to Training (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 012900 Physiology; 012500 Personnel Training & Evaluation							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
76 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING		b. FUNDS (in thousands)	
b. NUMBER: <sup>a</sup>				FISCAL YEAR		82	
c. TYPE:				CURRENT		4.0	
d. KIND OF AWARD:				83		146	
e. AMOUNT:							
f. CUM. AMT.							
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST, M. JR., COL, MSC				NAME: <sup>a</sup> VOGEL, JAMES A., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4800			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: DANIELS, WILLIAM L., MAJ, MSC, Ph.D.			
				NAME: JONES, BRUCE, CPT, MC, M.D. POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Muscular Strength; (U)Physical Fitness; (U)Training Injuries; (U)Aerobic Power; (U)Physical Training							
23. TECHNICAL OBJECTIVE, <sup>a</sup> 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
23. (U) Army physical fitness training doctrine is based largely on outdated information and has been slow in adopting new scientific concepts. Physical training in the Army could be made more effective and efficient by appropriate research to meet the Army's needs with this new knowledge and obtain new information in specific areas relevant to the Army (women, older age) where information is lacking.							
24. (U) Specific studies will include: (a) Determine the optimum mode, frequency, duration and intensity of training for different applications or needs; (b) Identify differences between men and women, if any, in the qualitative or quantitative response to training; (c) Establish suitable training programs for older age groups in the Army and (d) Document incidence of sports/training injuries and seek their prevention.							
25. (U) 81 10 - 82 09 (a) An epidemiological study of injuries incident to sports activities and physical training has begun its third year. Anatomical, physiological and flexibility factors are being related to injury incidence. No conclusions have yet been drawn. (b) Running in combat boots was found to cost 5 to 10% more in calories than running in athletic shoes. Such an increment becomes particularly important in low fat individuals during physical training. (c) Research on the screening of Army personnel for coronary artery disease was expanded to an under-40 year old population at Ft. Leavenworth, KA. Results are under analysis.							

<sup>a</sup>Available to contractors upon originator's approvalDD FORM 1498  
1 MAR 68

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 125 Physical Fitness Training and Prevention of Injuries Related to Training

Study Title: The Influence of Varying Dosages of Caffeine on the Substrate Utilization of Runners and Non-Runners

Investigators: Joseph J. Knapik, SP6. M.S., Bruce Jones, CPT, MC, M.D., Michael Toner, CPT, MSC, Ph.D. and William Daniels, MAJ, MSC, Ph.D.

Background:

Previous studies have indicated that caffeine (CAF) increases the mobilization and metabolism of free fatty acids (FFA) during prolonged exercise while sparing muscle glycogen (1,2). The mechanism by which caffeine improves endurance performance may be as follows. Caffeine stimulates the release of catecholamines (3) and inhibits phosphodiesterase (4). This causes an accumulation of cyclic AMP which, in adipose tissue, causes a breakdown of triglycerides into fatty acids and glycerol (5). Fatty acids are taken up by active muscle and the oxidation of these fatty acids inhibits glucose and glycogen oxidation in the muscle (6). Glucose and glycogen are thus spared for later in the endurance bout, increasing the time an activity can be performed.

Studies that have determined that caffeine can improve endurance performance (1,2) have all been performed on trained cyclists using only one dose of the drug. The question arises as to the relevance of this information in a military setting. Military personnel are generally considered to have above average aerobic fitness but do not fall into the elite category as do trained cyclists. Also the influence of higher dosages of caffeine cannot be ignored since larger amounts may further stimulate lipolysis and consequently further increase endurance. The purpose of this study was to determine the influence of two dosages of caffeine on changes in serum substrate levels in trained and untrained runners. The substrates included glycerol, free fatty acids (FFA), glucose and lactates. These substrates were the major ones hypothesized to be involved in increasing work performance.

### Progress:

From February to September of 1981, 5 untrained and 5 trained runners were tested. All trained individuals ran at least 20 miles per week and had a  $\dot{V}O_2$  max of at least 59 ml/kg min<sup>-1</sup>. All untrained subjects had a  $\dot{V}O_2$  max of < 50 ml/kg min<sup>-1</sup> and were involved in no regular running or other aerobic activities.

Preliminary testing consisted of a maximal oxygen uptake determination ( $\dot{V}O_2$  max) and a submaximal discontinuous test to determine the onset of blood lactate accumulation (OBLA). The experimental sessions consisted of three 1 hr runs separated by about two weeks each. Shortly after reporting to the laboratory, subjects ingested a premixed beverage containing either 0, 5 or 9 mg/kg body weight of anhydrous caffeine dissolved in a lemon-lime flavored drink sweetened with saccharin. Administration of the beverage was conducted in a double-blind fashion. One hour after ingesting the drink, subjects began running for 1 hr at 60%  $\dot{V}O_2$  max. During the run, an 11 ml blood sample was obtained from an indwelling catheter at 0 min, 5 min, and 10 min, and every subsequent 10 min. Respiratory exchange ratios (R values) were obtained at each time period just prior to blood collection.

Figure 1 shows the serum substrate data during the 1 hr run. There were no significant differences among the three sessions (2 CAF and 1 placebo) for the FFA. There was a trend toward higher glycerol levels (an indicator of FFA mobilization from the adipose tissues) during the CAF session ( $F(2,16) = 2.86$ ,  $p < .09$ ). However, R values did not change in either the T or UT subjects during the CAF sessions. This indicates that although CAF may have slightly increased FFA mobilization, it did not alter substrate utilization. Previous studies have shown that CAF stimulates mobilization and oxidation of FFA during prolonged exercise (1,2). These previous studies have used higher exercise intensities (70 - 80%  $\dot{V}O_2$  max) than the present study (60%  $\dot{V}O_2$  max). While CAF stimulates epinephrine release, it also potentiates the effects of existing epinephrine on FFA mobilization. The lower exercise intensity of the present study may have resulted in lower amounts of total circulating epinephrine on which CAF could exert a potentiation effect (7).

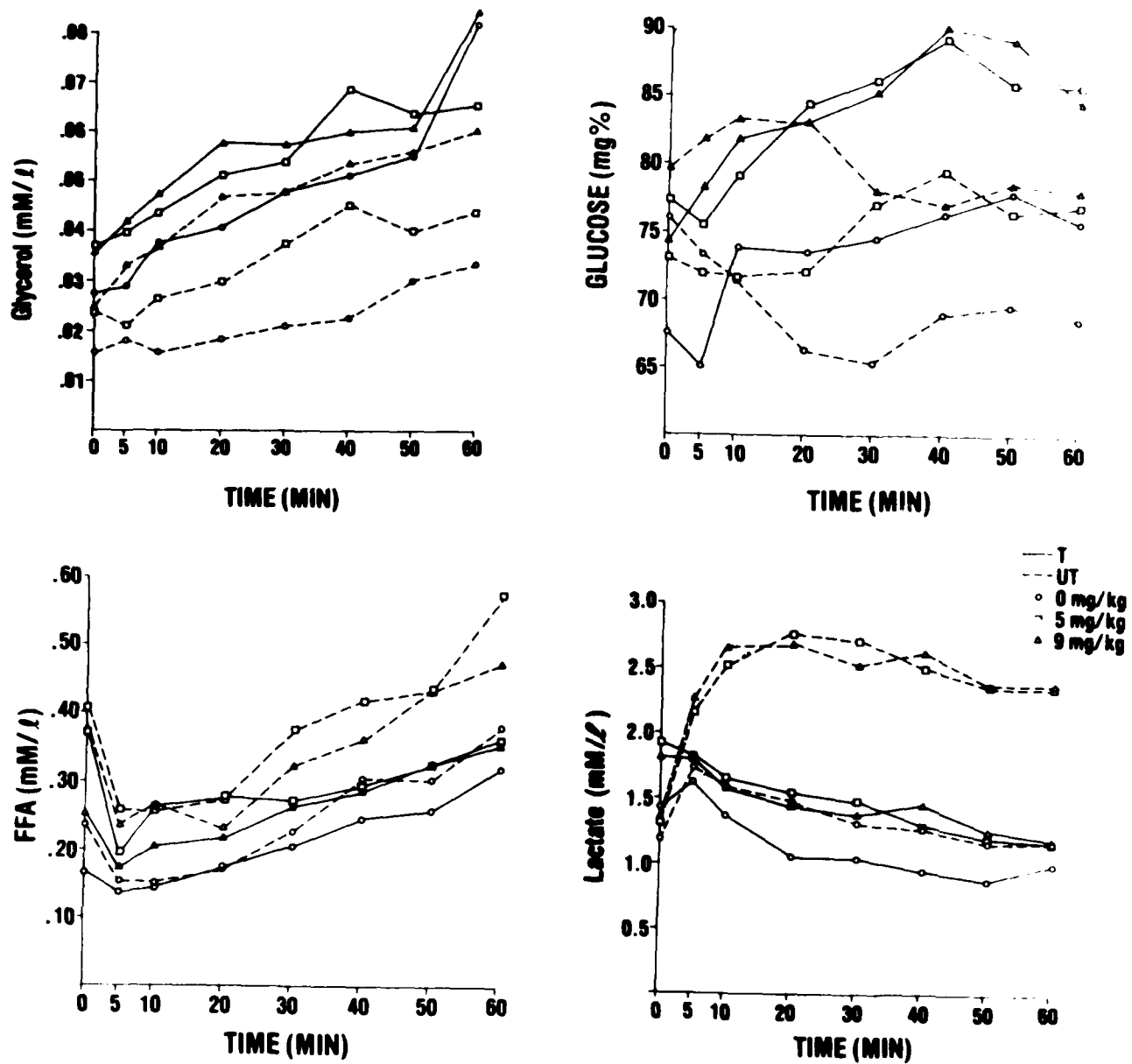


Figure 1. Serum substrate responses during a one-hour treadmill run.

Figure 1 also shows that there were higher serum glucose levels on both T and UT subjects during the CAF sessions. This may suggest a glycogenolytic effect of CAF. CAF is known to stimulate glycogenolysis in both liver and muscle (4). The dramatic increase in blood lactates in the UT (Fig. 1) also argues for increased glycolytic flux during the CAF sessions. The failure to see increased blood lactates in T subjects may be a result of enzymatic adaptations to training. Training results in less lactate accumulation at the same relative exercise intensity (8). There is a reduction in total LDH in muscle but an increase in the heart isozyme of the enzyme (9). Training also results in an increased ability to transaminate pyruvates to alanine (10).

#### Publications:

1. Knapik, J.J., B.H. Jones, M.M. Toner, W.L. Daniels and W.J. Evans. Influence of caffeine on serum substrate changes during running in trained and untrained individuals. Proceedings of the Fifth International Symposium on the Biochemistry of Exercise. (In press).
2. Knapik, J.J., B.H. Jones, M. M. Toner, W.L. Daniels and W.J. Evans. Influence of caffeine on serum substrate changes during running in trained and untrained individuals. Int. J. Sports Med. 3(2): Supplement, 1982.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 125 Physical Fitness Training and Prevention of Injuries Related to Training

Study Title: Health Risk Appraisal Program (HRAP) at the Command and General Staff College: Findings and Evaluation of the Multi-staged Cardiovascular Screening and Risk Intervention Component in a Predominantly Under-Forty Population

Investigators: William L. Daniels, MAJ, MSC, Ph.D., John F. Patton, Ph.D., James A. Vogel, Ph.D., Jerel Zoltich, MAJ, MC, M.D., WRAMC, Sandra Yaney, CPT, ANC, OTSC, Ken Glaser, CPT, MC, WRAMC, Julius Bedynek, COL, MC, M.D., OTSG, Larry Birch, CPT, MC, USA MEDDAC, Ft. Leavenworth, KS and Arden Aghton, MAJ, MC

#### Background:

As of 1 August 1980, the Chief of Staff, US Army, initiated a new physical training program for US Army personnel including individuals over 40 years of age who were previously exempt from physical training and testing. Because of the potential health risks of both training and testing to personnel in this age group, The Surgeon General proposed to medically screen all personnel over forty during their biannual physical examination in the form of a risk-factor analysis to predict the likelihood of untoward cardiovascular events. In support of this effort, two research studies were performed on personnel over 40 years of age to attempt to identify latent coronary artery disease (CAD). In one study, performed at Ft. Benning, GA between September 1980 and May 1981, 133 of 295 (45%) subjects tested were determined to be at an unacceptable level of risk for CAD based on the risk-factor analysis and would not be cleared for physical training and testing without further screening. In addition, 25 (8.5%) abnormal responses to a graded exercise treadmill test were also found.

In a second study, performed at the Army War College, Carlisle Barracks, PA in January 1982, this cardiovascular screen was given to 249 faculty and class members. Of these, 33 (13%) had coronary angiography because of abnormal findings primarily during the graded exercise tests.

Because of the significant (8.5% and 13.%) number of abnormal responses to graded exercise in these studies and because of two exercise-related deaths at Ft. Leavenworth, The Surgeon General's Task Force on physical fitness decided to investigate the effects of a cardiovascular risk screening and intervention program at the Command and General Staff College. Even though the majority of the students attending this school are under 40 years of age, it was decided that it would be beneficial to investigate the incidence of latent CAD in this population and evaluate the effects of an intervention program initiated prior to reaching forty years of age.

Progress:

As part of The Surgeon General's Task Force on Physical Fitness, members of the Exercise Physiology Division, USARIEM, assisted in performing the cardiovascular screen. During 7-10 September 1982, 124 members of the 1983 C&GS class were given a graded exercise test in order to detect any abnormal response to exercise. Of these, two individuals were sent to Fitzsimons AMC for coronary angiography with neither showing any signs of significant CAD. The overall abnormal response to exercise was very low compared to the two previous studies. All data is presently being collated by CPT Sandra Yaney of The Surgeon General's Task Force at Ft. Leavenworth and USARIEM's portion of the data will be analyzed as soon as it is received from Ft. Leavenworth.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 125 Physical Fitness Training and Prevention of Injuries  
Related to Training  
Study Title: Energy Cost of Walking and Running in Shoes and Boots  
Investigators: Bruce Jones, CPT, MC, M.D., Michael Toner, CPT, MSC,  
Ph.D., William Daniels, MAJ, MSC, Ph.D. and Joseph  
Knapik, SP6, M.S.

Background:

Because of the amount of time military personnel spend on their feet, especially in the field and during physical training, footwear is an important item affecting the comfort and health of the soldier. In the past, protection of the feet, durability and comfort have been important factors in the design and selection of military footwear. Another factor which has received relatively little attention in the past is the impact of different types of footwear on the energy cost of walking and running.

Soule and Goldman demonstrated that loads carried on the feet increased the energy cost of walking 4-6 times that of the same weight carried elsewhere on the body (1). A few other studies (2, 3, 4) have demonstrated an increase in energy cost of walking with increase in the weight of footwear. Most of the studies examined the responses of only one or two subjects and none of them examined the effect of footwear on the energy cost of running.

With the increased emphasis on aerobic training, primarily running, in military populations, there is an even greater need to study the impact of footwear on physical performance. If different types of footwear substantially increase or decrease the energy cost of walking and running, this could effect not only performance but also injury rates as a result of fatigue.

Because of subjective experience and examination of P.T. test performances in shoes and boots, it was felt that shoes would substantially reduce the energy cost of walking and running. This study was designed to examine and compare the energy cost of walking and running in shoes and boots.

### Progress:

The study has been completed. Twenty-one subjects participated in the study, 14 males and 7 females. The data for males have been analyzed, but data for females have not. Of the males who participated, 8 were untrained and 6 trained.

To determine the difference in the energy cost of walking and running in a lightweight running shoe and the combat boot, the subjects had their maximum oxygen uptake ( $\dot{V}O_{2\max}$ ) measured and were further characterized by weight, height and percent body fat (skinfold-measures from 4 sites)(5). The subjects wore each type of footwear, an athletic shoe (avg. wt. per pair 616g), and the standard combat boot (avg. wt. 1776g per pair) while walking at 3 speeds (2.5, 3.5, 4.5 mph) and running at 3 speeds (5.5, 6.5 and 7.5 mph).  $\dot{V}O_2$  and heart rate were measured during these trials. The  $\dot{V}O_2$  values with boots were significantly higher ( $P < .05$ ) at all speeds except walking at 2.5 mph (see Table 1). The absolute energy cost of walking or running was the same for both trained and untrained subjects.

While absolute energy costs were the same for both groups, the untrained subjects performed at much higher percents of their  $\dot{V}O_{2\max}$  and higher heart rates.

These data indicate that energy expenditure is increased by wearing boots. This may be related to the increased weight of the boots and/or to biomechanical limitations imposed by boots. Also, state of training did not affect the absolute energy cost.

The added energy cost of wearing boots as opposed to shoes for physical training could have important implications, especially for untrained individuals who are performing at much higher, possibly limiting heart rates and percents of their  $\dot{V}O_{2\max}$ .

TABLE 1

Average  $\dot{V}O_2$  ( $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) of subjects walking and running on a Treadmill in Different Types of Footwear  
(T = Trained, UT = Untrained C = Combined, T + UT)

<u>WALKING</u>										
Speed (mph)		2.5			3.5			4.5		
		T	UT	C	T	UT	C	T	UT	C
Shoes	$\bar{X}$	10.9	10.3	10.5	13.8	14.6	14.2	20.3	22.7	21.7
	S.D.	0.5	1.4	1.1	0.6	1.5	1.3	0.8	3.0	2.6
	N	6	8	14	6	8	14	6	8	14
Boots	$\bar{X}$	11.8	10.6	11.1	15.2	15.2	15.4	22.2	24.3	23.4
	S.D.	0.6	1.5	1.4	0.4	1.4	1.1	0.9	2.6	2.1
	n	6	8	14	6	8	14	6	8	14
$\Delta \dot{V}O_2$		.6			1.2			1.7		
$\% \Delta \dot{V}O_2$		5.9			8.4			7.9		
p*		n.s.			< .05			< .05		

<u>RUNNING</u>										
Speed (mph)		5.5			6.5			7.5		
		T	UT	C	T	UT	C	T	UT	C
Shoes	$\bar{X}$	30.1	30.7	30.4	35.0	35.6	35.2	39.5	39.4	39.6
	S.D.	1.5	1.5	1.4	2.3	1.9	2.0	2.5	2.6	2.3
	n	6	8	14	6	8	14	6	8	14
Boots	$\bar{X}$	32.9	34.1	33.6	37.9	38.5	38.2	43.3	41.7	42.9
	S.D.	0.6	2.3	1.9	2.1	1.7	1.9	2.5	2.1	2.1
	n	6	8	14	6	8	14	6	8	14
$\Delta \dot{V}O_2$		3.1			2.9			3.2		
$\% \Delta \dot{V}O_2$		10.2			8.1			7.3		
p*		< 0.5			< .05			< .05		

\*p = Level of significance for difference in energy cost of between walking and running in shoes and boots for combined group (c).

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E1627777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 125 Physical Fitness Training and Prevention of Injuries  
Related to Training

Study Title: Physical Fitness and Sports Injuries in Female Athletes

Investigators: Joseph Knapik, SP6, M.S., Connie Bauman, M.S., A.T.C.,  
John Harris, M.D., Bruce Jones, CPT, MC, M.D. Mildred  
Henry, RPT, James Wright, CPT, MS, Ph.D.

Background:

Prevention of injuries is a major concern of both scientists and clinicians. It has been suggested that certain anatomic and physiologic characteristics may predispose women to certain types of injuries that are less common in men (1). Several military studies to date have indicated that females are more susceptible to stress related injuries in basic training than their male counterparts (2, 3). However, civilian studies of high school (4), intercollegiate (5), and recreational athletes (6) have shown that although there is some difference in the distribution and incidents of injuries between male and female athletes, these differences are not as great as in the military studies. This contrast may suggest that when females are required to train at the same intensity as men at the start of a program, they are more likely to suffer injuries than when they are allowed to train and compete at their own level.

The purposes of this study were threefold: First, to ascertain which injuries occur in females exposed to several types and levels of physical activity (represented by a variety of intercollegiate sports); second, to determine to whether the incidence of injuries is related to various components of physical fitness, namely, strength, flexibility, body composition and body anthropometry; third, to determine if it was possible to develop a battery of tests that would predict risk of injury.

Progress:

In the 1980-1981 academic year 106 females at Wellesley College, Wellesley, MA. were tested. The test battery and results were presented in a previous

progress report (7). Because of the small number of injuries in this first study, it was decided to continue the investigation into the next year. In the first year (Year I), 10 athletic teams were tested. In the second year (Year II) the number of teams were reduced on the basis of the number and type of injuries seen. In Year II 6 teams were studied: Soccer (SOC), Volleyball (VB), Field Hockey (FH), Crew, Basketball (BB) and LaCrosse (LC).

The test battery has been described in the earlier progress report (7). The methods were identical in Years I and II for the physical characteristics and the static and dynamic strength measures. A T-test demonstrated no significant difference between the two years on any of these measures. Some refinements were undertaken in the flexibility, hypermobility, body segmental length and angular measures in order to improve the reliability of these tests. These refinements resulted in a significant difference (T-test) between Year I and II on most of these tests.

In Year II, 73 subjects were tested and were distributed in the following manner by team: SOC, 17; VB, 9; FH, 9; Crew, 14; BB, 10; LC, 14. Twenty-four of these 73 subjects (33%) were also tested on Year I.

There were a total of 39 injuries in Year II. Quadricep strains and ankle sprains were the most frequent injuries accounting for 31% of the total (12 of 39). All strain and sprain injuries combined accounted for 64% of the total injuries (25 of 39). Various tendonitis injuries accounted for 15% of the total (6 of 39). Injury data in the previous progress report (7) reflects only time loss injuries while in Year II both time loss and non time loss injuries were included. If both types of injuries are included for the 6 selected sports in Year I, there were a total of 46 injuries in Year I. Thus, there was a 30% injury reduction in Year II. The fewer number of tendonitis injuries in Year II compared to Year I reflects the exclusion of the swimming, squash and tennis teams who had the large majority of these overuse injuries in Year I.

Several hypotheses regarding predisposing factors to injury were tested using a  $X^2$  analysis and the data from Years I and II. Year I data indicated that a muscular imbalance of  $> 15\%$  between the right and left knee extensor strengths was significantly related to quadricep strains (7). This finding could not be substantiated with the Year II data nor with the combined data of Years I and II. Neither quadricep strains nor ankle strains were related to Q Angle or any hypermobility measure. Hyperextension knee strains were not related to any strength or hypermobility measure. Neither shin splints nor tendonitis were

related to foot pronation angle. Thus,  $X^2$  analysis did not reveal any predictors of injury.

Because of continued refinement in methods and the possibility of collecting additional injury data, the study will be continued. It seems possible that quadricep strains and ankle sprains are a common enough injury in this sample to allow for a discriminate function or multiple regression analysis with one additional year of data collection.

#### Publications:

1. Bauman, C.L., Knapik, J.J., Jones, B.H., Harris, J.M. and Vaughn, L.K. An Approach to Musculoskeletal Profiling of Women in Sports. In: R. Cantu and W. Gillespie (Eds.), Sports Medicine, Sports Science: Bridging the Gap. Lexington, MA: D. C. Heath, 1982.
2. Knapik, J.J., B.H. Jones, C. Bauman, J. Harris and J.E. Wright. Relationship between peak torque, average torque and total work in an isokinetic contraction. *Medicine and Science in Sports and Exercise*, 14:178, 1982.

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6. Clement, D.B., Taunton, J.E., Smart, G and McNicol, K.L. A survey of overuse running injuries. *Phys. Sports Med.* 9:47 - 48, 1981.
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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1 AGENCY ACCESSION <sup>a</sup>	2 DATE OF SUMMARY <sup>a</sup>	REPORT CONTROL SYMBOL	
				DA OA 6148	82 09 30	DD FORM 1498-1	
3 DATE PREV SUMMARY	4 KIND OF SUMMARY	5 SUMMARY SCTY <sup>a</sup>	6 WORK SECURITY <sup>a</sup>	7 REGRADING <sup>a</sup>	8a DISSEM INSTR <sup>a</sup>	8b SPECIFIC DATA CONTRACTOR ACCESS	9 LEVEL OF SUM
82 04 30	D.CHANGE	U	U		NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	A. WORK UNIT
10 NO. CODES <sup>a</sup>	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER			
A. PRIMARY	62777A	3E162777A879	BC	126			
B. CONTRIBUTING							
C. COORDINATING	XXXXXX	STOG 81-7.2:3					
11. TITLE (Precede with Security Classification Code) <sup>a</sup> (U)Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS <sup>a</sup> 012600 Pharmacology; 005900 Environmental Biology; 013400 Physiology							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
70 07		CONT		DA		C. IN-HOUSE	
17. CONTRACT GRANT				18. RESOURCES ESTIMATE		19. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE.				PRECEDING		b. FUNDS (In thousands)	
B. NUMBER <sup>a</sup>				FISCAL YEAR		82	
C. TYPE				CURRENT		9.0	
D. KIND OF AWARD				83		307	
E. AMOUNT:				9.0		307	
F. CUM. AMT.							
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME: <sup>a</sup> USA RSCH INST OF ENV MED				NAME: <sup>a</sup> USA RSCH INST OF ENV MED			
ADDRESS: <sup>a</sup> NATICK, MA 01760				ADDRESS: <sup>a</sup> NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: <sup>a</sup> MAHER, JOHN T., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4852			
21. GENERAL USE				ASSOCIATE INVESTIGATORS			
Foreign Intelligence Not Considered				NAME: CYMERMAN, ALLEN, Ph.D.			
				NAME: BURSE, RICHARD L., Sc.D. POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Volunteers; (U)Acute Mountain Sickness; (U)Altitude Acclimatization; (U)Hypobaric Hypoxia; (U)Pulmonary Edema; (U)Performance Decrements							
23. TECHNICAL OBJECTIVE. <sup>a</sup> 24. APPROACH; 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Exposure of soldiers to high terrestrial elevations results frequently in reduced military performance as well as medical disabilities which are incompatible with the successful completion of military operations. The purpose of this work unit is to characterize these performance decrements and disabilities and to investigate the basis of and methods for their prevention and treatment.</p> <p>24. (U) Studies will be conducted in man to: (a) determine the mechanisms of the physiologic alterations and medical disabilities at altitude; (b) assess and predict the performance of individuals and small units operating at altitude; (c) evaluate the efficacy of pharmacological agents and other means in preventing or reducing performance decrements and illness; (d) enhance the rate of adaptation to high terrestrial elevations.</p> <p>25. (U) 81 10 - 82 09 (a) The standard course of acetazolamide treatment for reducing the severity of acute mountain sickness upon ascent to high altitude induced a significant acidosis in soldiers at both sea level and at 4,300 meters; despite this, the normal maximum work capacity at sea level and the reduced maximum capacity at altitude were not affected by the treatment; (b) Standing steadiness or body sway was not altered in soldiers suffering from acute mountain sickness at 4,300 meters; (c) Stroke volume and cardiac output responses of soldiers to a change in posture were significantly altered during high-altitude exposure but bore no relationship to either acetazolamide administration or the occurrence and intensity of mountain sickness symptoms; (d) Neither ascent to 4,300 meters nor acetazolamide treatment significantly affected endurance times to exhaustion at workloads set at 90% of the available maximum work capacity; (e) Measurement of the hypoxic ventilatory response of volunteers at low altitude allowed prediction of well-being and performance during a subsequent high-altitude exposure.</p>							

<sup>a</sup>Available to contractors upon originator's approval.

DD FORM 1498  
1 MAR 68

PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 126 Prevention and Treatment of Disabilities Associated  
with Military Operations at High Terrestrial Elevations

Study Title: Effect of Acetazolamide on Maximal Exercise Capacity and  
Submaximal Endurance Performance at Altitude

Investigators: Richard L. Burse, Sc.D., Allen Cymerman, Ph.D., Paul B.  
Rock, CPT, MC, Ph.D., D.O., William C. Daniels, MAJ,  
MSC, Ph.D., James B. Sampson, Ph.D., Robert C. Feccia,  
SP5, M.S. and John T. Maher, Ph.D.

Background:

Acute mountain sickness (AMS) is characterized by headache, fitful sleep or frank insomnia, upset stomach, nausea, anorexia, irritability, breathlessness at rest, lassitude and general malaise (1-4). Symptoms occur in a few individuals at elevations as low as 2,500 meters and in nearly everyone at 4,500 meters, often to the degree that a fully trained soldier is unable to care for himself. Because of the frequency of occurrence and its severe effect on some individuals, AMS can become a critical problem in the conduct of military operations by troops rapidly transported to high altitude. At present the best method for minimizing the symptoms in troops ascending to high altitude is a combination of acetazolamide and partial acclimatization by brief residence for several days at intermediate altitudes (staging) or, if staging is not feasible, acetazolamide alone. Current military medical doctrine, contained in TB MED 288, recommends a daily dose of 1,000 mg acetazolamide for two days prior to ascent and for the first two days at altitude.

The soldier's maximal capacity for physical work or exercise is markedly reduced upon ascent to altitude and remains so for many months, if not years, of continued altitude exposure. Data from this laboratory indicates that the maximum work capacity is only 70-80% of the former sea-level value at altitudes of 4,000 to 4,300 meters (13,000 to 14,000 feet), even after altitude acclimatization. Because of the reduced maximum work capacity, the soldier's ability to perform a given level of submaximal exercise for prolonged periods is

also reduced at altitude. The altitude effect is to make any given submaximal work task relatively more severe at altitude and thereby to shorten endurance time.

Acetazolamide induces a metabolic acidosis (1,5,6). This acidosis offers the potential for reducing both maximal work capacity and submaximal endurance of troops who have been administered the drug before ascending to altitude, either by interfering with the respiratory alkalosis which develops at altitude or by altering the chemical environment of the working muscles. In one study, acetazolamide reduced the maximum power output that could be produced at sea-level by 7% (7). Another study, also at sea-level, showed that a metabolic acidosis shortened endurance time for submaximal exercise, while a metabolic alkalosis prolonged endurance time (8). The endurance capacity at altitude of troops taking or not taking acetazolamide in accordance with the current military medical doctrine has been compared in but a single study (6). This study involved an exercise task that could be performed an average of 40 min at sea-level but only 8 min at altitude, with the result that there was no difference between the endurance performance of the group treated with acetazolamide and the group left untreated. Since the endurance task was not adjusted for the decrements in performance that occurred at altitude, it was too severe to be a reasonable test with which to judge the effects of acetazolamide.

Quantitative information concerning the effects of acetazolamide on maximum work capacity and submaximal endurance is needed in order to specify both the degree and variability of the performance limitations induced by the drug in soldiers at altitude. This information will aid commanders to realistically plan troop operations at altitude. It also will indicate whether the current military medical doctrine concerning acetazolamide is adequate or whether the recommended dosage and schedule need to be altered to maintain effective prophylaxis against AMS, while minimizing any unwanted effects on physical performance.

#### Progress:

The effect of acetazolamide on maximum oxygen uptake ( $\dot{V}O_2$  max), a measure of maximum work capability, and on endurance time to exhaustion for working at 90% of the preceding  $\dot{V}O_2$  max (ET 90) was determined in a drug administration study of double-blind design. Twelve healthy young male

volunteers from the local military test subject platoon signed statements of informed consent after receiving a detailed briefing of the procedures and risks involved. They then underwent a 6-week preliminary testing phase at sea level, during which period  $\dot{V}O_2$  max and ET 90 were determined weekly (one day apart) in order to obtain stable baseline values. Following the preliminary phase, the subjects were randomly assigned to an experimental group (n=7) and a control group (n=5) for a 2-day period of drug treatment at sea level, a 3-day period at altitude (Pikes Peak, 4,300 m) while drug treatment was continued, and a 3-day period at altitude after drug treatment was stopped. During the drug treatment periods, the experimental group received 500 mg acetazolamide b.i.d. and the control group received a lactose placebo of identical appearance on the same schedule.  $\dot{V}O_2$  max was redetermined at sea level during the period of drug treatment, on the second day at altitude while treatment was continued and at altitude on the second day after treatment was stopped. ET 90 was redetermined only at altitude, on the day after the two  $\dot{V}O_2$  max tests (during and after the drug treatment).  $\dot{V}O_2$  max values were determined on a cycle ergometer using an interrupted protocol of successive 4 min exercise bouts separated by 3 min rest periods, with the work intensity increased 25 W in each successive bout until  $\dot{V}O_2$  (open circuit spirometry) plateaued or increased no more than 1.5 ml/min  $\cdot$  kg, despite the increased work intensity. ET 90 was measured on the cycle ergometer after two preliminary 15 min warm-up bouts at 33% and 66%  $\dot{V}O_2$  max, with 3 min rest periods between bouts. Blood pH,  $PO_2$  and  $PCO_2$  were measured before each test; blood lactate concentrations were measured in duplicate in the final 30 sec of and 3 min after the final work bout of each test.

Preliminary analysis of the  $\dot{V}O_2$  max, ET 90 and blood pH results indicated no significant effect of acetazolamide on the work intensity eliciting  $\dot{V}O_2$  max or ET 90, either at sea level or at altitude, despite the expected significant reduction in blood pH. As shown in Table 1, acetazolamide treatment resulted in a minor, yet significant, reduction of 4% in  $\dot{V}O_2$  max at sea level and the same change at altitude which was not significant. Altitude resulted in the expected marked reduction ( $p < 0.001$ ) in  $\dot{V}O_2$  max in both groups (30% in the control group, 29% in the experimental group).

Table 2 shows the results for ET 90. The experimental group had a consistently, but not significantly, longer ET 90 than the control group. Mean values at altitude showed no significant effect of either acetazolamide or placebo. They were remarkably similar to those achieved at sea level, despite

the dramatic reduction in  $\dot{V}O_2$  max and therefore the work intensity at which the ET 90 tests were performed.

Detailed analysis of the results for the measured cardiorespiratory parameters (ventilation, heart rate,  $\dot{V}O_2$ ,  $\dot{V}CO_2$ , RQ) and blood variables (pH,  $P_{O_2}$ ,  $PCO_2$ , lactate levels) is being continued. If the preliminary findings are confirmed, it can be concluded that acetazolamide treatment in accordance with the instructions in TB Med 288 has no meaningful effect on the soldier's maximum work capacity or physical endurance at either sea level or high altitude.

Table 1  
Mean  $\dot{V}O_2$  max ( $\pm$  SE) of placebo (n=5) and acetazolamide (n=7)  
groups at sea level (SL) and 4,300 m altitude (HA),  
with and without drug treatment

Condition	$\dot{V}O_2$ max ( $l \cdot min^{-1}$ )	
	Placebo	Acetazolamide
SL, no treatment	4.00 $\pm$ 0.27	3.78 $\pm$ 0.23
SL, drug treatment	3.99 $\pm$ 0.23	3.64 $\pm$ 0.20#
HA, drug treatment	2.81 $\pm$ 0.20*	2.58 $\pm$ 0.11*
HA, no treatment	2.75 $\pm$ 0.15*	2.68 $\pm$ 0.12*

\* = HA value differs from corresponding SL value ( $p < 0.001$ ).

# = drug treatment value differs from corresponding no treatment value ( $p < 0.025$ ).

Table 2  
Mean endurance times ( $\pm$  SE) to exhaustion at 90%  $\dot{V}O_2$  max of  
placebo (n=5) and acetazolamide (n=7) groups at sea level (SL) and  
at 4,300 m altitude (HA), with and without drug treatment.  
No difference found to be significant.

Condition	ET (minutes)	
	Placebo	Acetazolamide
SL, no treatment	6.6 $\pm$ 1.0	9.1 $\pm$ 1.1
HA, no treatment	6.7 $\pm$ 0.8	9.0 $\pm$ 1.1
HA, drug treatment	6.6 $\pm$ 0.5	8.1 $\pm$ 1.2

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Program Element: 6.27.77.A Medical Factors Limiting Soldier Effectiveness  
Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness  
Work Unit: 126 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations  
Study Title: Cardiocirculatory Responses to Postural Changes at High Altitude: Effect of Exposure Time and Acetazolamide  
Investigators: Allen Cymerman, Ph.D., Charles S. Fulco, M.A.T., Richard L. Burse, Sc.D., Paul B. Rock, CPT, MC, Ph.D., D.O. and John T. Maher, Ph.D.

Background:

A complex series of physiological adjustments occur when man is exposed to the hypoxia of high altitude. There are immediate respiratory and circulatory adjustments exemplified by increases in ventilation, heart rate and cardiac output. Although there are several studies relating the insensitivity of the ventilatory response to altitude illnesses such as acute mountain sickness (AMS) and pulmonary edema, there are studies which implicate circulatory responses in the process (1,2). This study investigated the effects of a change in posture from recumbency (15 min) to standing (15 min) on cardiac output and peripheral blood flow at sea level and during 5-days exposure to 4,300 meters using the impedance cardiographic technique. By examining blood flow in the calf in reclining and standing positions, compensatory circulatory mechanisms can be observed which may be related to AMS. One purpose of this study was to determine whether a correlation exists between the circulatory responses and AMS. Individuals who exhibit unusual responses may be at either end of the severity spectrum. However, if a correlation is demonstrable then an objective, quantifiable physiological response may prove to be of important predictive value. A second purpose of this study was to document the circulatory responses over the course of 5-days altitude exposure. Orthostatic or postural influences on cardiac output have not been demonstrated previously with an exposure of this duration. A third purpose was to determine the possible effect of acetazolamide, a drug presently prescribed for the amelioration of AMS, on the circulatory responses.

### Progress:

Twelve enlisted volunteers were each tested three times at sea level and on days 1,2,3 and 5 of exposure to 4,300 m altitude. Forty-eight hours before and after ascent each subject received either drug or placebo (500 mg; b.i.d.). Thoracic and peripheral impedance data were collected using 6 ECG electrodes and an impedance cardiograph. The basic technique employs two pickup electrodes on the back and two on the calf. A constant sinusoidal current (4 mA rms) with a frequency of 100 kHz was applied between an electrode on the forehead and ankle bone. Thoracic impedance changes via the back electrodes were used to determine stroke volume and cardiac output while the two calf electrodes were used to determine calf blood flow, normalized to 100 ml. Each trial consisted of measurements taken after 15 min of recumbency and again after 15 min of standing.

No statistically significant relationship was found between any circulatory measurement and either the severity of AMS reported by the subjects or acetazolamide administration.

Upon standing from a recumbent position, baroreceptor stimulation results in a sympathetic vasoconstrictor response to maintain blood pressure. Usually compensatory responses are incomplete and result in reduced venous return to the heart and a lower cardiac output. Table 1 shows the central cardiocirculatory values during recumbency and standing as well as the response. Supine stroke volumes averaged 107 ml for the 3 test days at sea level and 85 ml at altitude. Averaged standing stroke volume at sea level was 63 ml, remained similar for the first 2 days at altitude, and was reduced to 48 ml on days 3 and 5. Overall, the reduction in stroke volume was 41% at sea level and 36% at altitude. Cardiac outputs were elevated from the first day of exposure, but fell progressively to sea-level values thereafter. The average sea-level supine cardiac output was 6.1 l/min and at altitude was 5.7 l/min. The standing cardiac output showed a similar difference between sea level and altitude - 4.4 and 5.0 l/min, respectively. Heart rates were increased immediately upon exposure and remained elevated for both body positions - 10 bpm increase for the supine position and 21 bpm for the standing. This increase in heart rates is the primary factor responsible for the transient increase in cardiac outputs. The heart rate response to a postural change showed the most consistency throughout the exposure period. The increase at sea level averaged 24% from supine to standing while at altitude the increase averaged 36%.

Table 2 illustrates the results of the peripheral circulatory determinations. Normalized calf blood flows in both the supine and standing positions were increased during altitude exposure; 4.8 to 5.3 ml/min/100 ml for supine and 3.1 to 3.8 ml/min/100 ml. This increase is associated with a small but significant rise at altitude in mean arterial blood pressure in both body positions -5 Torr in the supine and 3 Torr in the standing position. Proportional increases in both pressure and calf flow resulted in no consistent change in calculated peripheral resistance, the quotient of pressure and flow. Except for the first sea-level test day, the blood pressure responses were always less at altitude. Baseline impedance values can be used to provide an indication of blood pooling. The last column of Table 2 shows that there were consistently lower values for calf blood pooling at altitude than at sea level.

These results are indicative of a generalized peripheral vaso- and venoconstriction which allows the maintenance of blood pressure and adequate tissue perfusion without blood pooling and the consequent peripheral edema and increased clotting potential. These results are also consistent with the circulatory effects of the well-known rise in norepinephrine levels at altitude.

In conclusion, acetazolamide administration did not alter any cardiocirculatory measurements in this study. Although there were large variations between individuals, there was no demonstrable relationship with the severity of acute mountain sickness. The reduced cardiac output and blood pressure responses and the increased heart rate response are physiological reflexes that are evident immediately upon exposure and persist for at least 5 days. Since AMS symptoms have resolved for the most part by this time, these reflexes do not appear to be causally related to illness.

TABLE 1

Central cardiocirculatory responses to a change in posture during exposure to high altitude. Mean  $\pm$  SE, N = 12

Condition	Day	Stroke Volume (ml)			Cardiac Output (l/min)			Heart Rate (bpm)		
		Supine	Standing	%	Supine	Standing	%	Supine	Standing	%
sea level	1	109 $\pm$ 6	70 $\pm$ 6	-36	6.13 $\pm$ .25	4.77 $\pm$ .49	-23	57 $\pm$ 3	69 $\pm$ 3	35
	2	104 $\pm$ 8	57 $\pm$ 5	-45	6.16 $\pm$ .48	4.19 $\pm$ .22	-32	60 $\pm$ 3	77 $\pm$ 3	35
	3	109 $\pm$ 9	63 $\pm$ 4	-42	5.92 $\pm$ .41	4.29 $\pm$ .29	-28	56 $\pm$ 2	69 $\pm$ 3	38
altitude	1	100 $\pm$ 7	64 $\pm$ 5	-36	6.50 $\pm$ .48	5.51 $\pm$ .46	-15	66 $\pm$ 3	88 $\pm$ 4	31
	2	84 $\pm$ 6	60 $\pm$ 5	-29	5.60 $\pm$ .37	5.39 $\pm$ .42	-4	68 $\pm$ 4	91 $\pm$ 5	28
	3	80 $\pm$ 7	47 $\pm$ 6	-41	5.16 $\pm$ .32	4.35 $\pm$ .36	-16	66 $\pm$ 3	92 $\pm$ 5	31
	5	77 $\pm$ 6	49 $\pm$ 4	-36	5.56 $\pm$ .38	4.72 $\pm$ .38	-5	73 $\pm$ 5	99 $\pm$ 5	22

TABLE 2

Peripheral circulatory responses to a change in posture during exposure to high altitude. Mean  $\pm$  SE, N = 12

Condition	Day	Calf Blood Flow (ml/min/100 ml)			Mean Arterial Pressure Torr			Blood pooling ml/100 ml	
		Supine	Standing	%	Supine	Standing	%		
sea level	1	4.9 $\pm$ .3	3.3 $\pm$ .5	-32	84 $\pm$ 3	88 $\pm$ 4	5	4.4 $\pm$ .4	
	2	5.0 $\pm$ .4	3.1 $\pm$ .2	-38	83 $\pm$ 2	93 $\pm$ 2	12	4.9 $\pm$ .7	
	3	4.5 $\pm$ .4	2.8 $\pm$ .2	-38	83 $\pm$ 2	91 $\pm$ 4	10	5.4 $\pm$ .8	
altitude	1	5.1 $\pm$ .3	3.8 $\pm$ .4	-26	89 $\pm$ 3	95 $\pm$ 2	6	3.6 $\pm$ .5	
	2	5.5 $\pm$ .4	3.6 $\pm$ .2	-36	89 $\pm$ 2	94 $\pm$ 4	6	4.1 $\pm$ .7	
	3	5.3 $\pm$ .3	3.5 $\pm$ .2	-35	87 $\pm$ 2	95 $\pm$ 2	9	4.3 $\pm$ .4	
	5	5.1 $\pm$ .3	4.5 $\pm$ .6	-12	88 $\pm$ 2	93 $\pm$ 3	6	4.2 $\pm$ .4	

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 126 Prevention and Treatment of Disabilities Associated  
with Military Operations at High Terrestrial Elevations  
Study Title: Visual Input into Maintenance of Balance During Exposure to  
High Altitude  
Investigators: Allen Cymerman, Ph.D. and Charles S. Fulco, M.A.T.

Background:

Dizziness and fatigue are usual occurrences during acute exposures to hypoxia and have been associated with altitude-induced illnesses (1,2,3). Whereas dizziness has long been subjectively perceived at altitude, there has been little quantitative information which could be used to study susceptibility of individuals to altitude-related illnesses and the severity of such illnesses when they occur. In a previous study (USARIEM Annual Progress Report, 1981), we reported the first phase in the quantification of body sway in individuals under normal sea-level conditions with the goal of using the method to assess severity of acute mountain sickness and/or subclinical cerebral edema. In that report subjects were asked to stand on a 60 x 40 cm piezoelectric multicomponent force platform which measured point-of-force application in the lateral and anteroposterior planes. The experimental sequence was: feet adjacent, eyes open (16 sec) and closed (16 sec), and feet in tandem, eyes open (16 sec) and closed (16 sec). Data were collected and analyzed by digital computer. This sequence was repeated three times and the best score was used as representative of that trial. Scores were first determined using areas of power spectra generated by Fast Fourier Transformation (FFT). This was found to produce a large variability in subject scores when a reliability study was performed using several subjects over the course of one week.

Progress:

We have subsequently switched to a much simpler method of quantification. The summation of consecutive triangular areas formed by the

resultant x-y force vectors appears to produce much more stable and reproducible results.

This new analysis procedure was used to study the effects of 16 days exposure to 4,300 meters on 8 subjects. Figure 1 shows the results of standing with feet in tandem at sea level (0 day) and at altitude. Of the four test conditions, feet-in-tandem produced the most consistent results. Although not statistically significant, body sway increased 24% on day 2 and 28% on day 5 and then improved during the next 11 days. There was no change when the visual input to balance was removed, inferring that 4300 m altitude did not cause a greater reliance on vision.

Quantification of body sway using force platform techniques shows promise as a means to study hypoxia-induced impairments of mental and psychomotor performance as well as possible subclinical edema. It appears that 4,300 meters is a borderline altitude with respect to distinguishing disruptions in performance. It has been shown that rapid onset of severe hypoxia (breathing a 10% oxygen mixture, equivalent to 5,790 meters) was sufficient to produce marked changes in body steadiness; however, using FFT analysis the variation was still quite large (4). The present analysis technique will be used on a future study at equivalent altitudes or higher to determine whether the technique is sufficiently sensitive to detect functional balance disorders when they are more likely to occur.

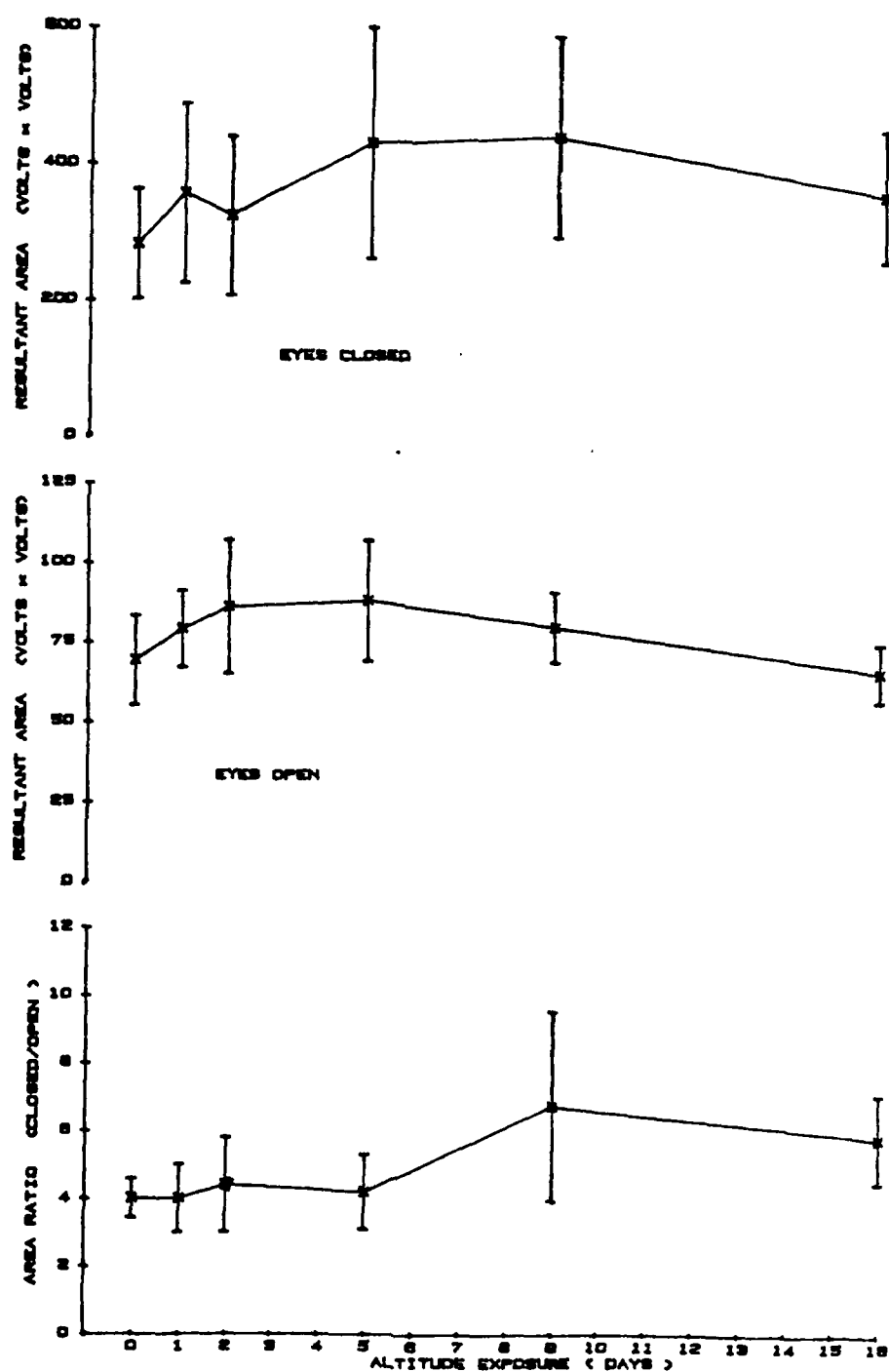


Figure 1. Body sway determinations during exposure to 4,300 meters, Mean  $\pm$  SE. N=8. Top: eyes closed. Middle: eyes open, Bottom: ratio of closed/open.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 126 Prevention and Treatment of Disabilities Associated  
with Military Operations at High Terrestrial Elevations

Study Title: Effects of High-Altitude Exposure on Muscle Metabolism  
During Exercise

Investigators: Andrew J. Young, CPT, MSC, Ph.D., Robert C. Feccia, SP5,  
M.S., Allen Cymerman, Ph.D. and John T. Maher, Ph.D.

Background:

Short-term residence at high altitude (HA) has been shown to result in alterations in the metabolism of substrate during exercise. When exercise of the same relative intensity ( $\% \dot{V}O_2 \text{ max}$ ) and duration is performed at sea level (SL) and immediately upon arrival at HA, there is no difference in the amount of muscle glycogen used or the amount of lactate in the blood (1). After 18 days residence at HA, less muscle glycogen is used during the exercise bout and post-exercise blood lactate concentration is lower as compared to SL (1). The mechanism for this apparent reduction in the rate of glycolysis during exercise is unknown, although a concomitant increase in the utilization of fat may be associated with the adaptation.

The purpose of the present study was to further elucidate biochemical alterations induced in skeletal muscle of SL natives residing temporarily at HA. Specifically, the effect of an 18-day exposure to HA (4,300 meters) on the skeletal muscle activity of several glycolytic and oxidative enzymes in SL natives was studied. In addition, the influence of short-term (15 days) residence at 4,300 meters on blood lactate accumulation during progressive exercise was determined. Finally, the change in skeletal muscle pH during exercise was measured at SL and at 4,300 meters after 15 days residence.

Progress:

The changes in muscle metabolism during exercise resulting from chronic HA exposure are similar to changes which result from adaptation to chronic

endurance training. Endurance training increases skeletal muscle activity of hexokinase (2), and malate dehydrogenase (3), and decreases the activity of lactate dehydrogenase and glycogen phosphorylase (2). Vastus lateralis muscle samples were obtained from 5 healthy, young male soldiers at SL (50 meters) and after 18 days of continuous residence at Pikes Peak (4,300 meters). The muscle samples were obtained by needle biopsy and stored in liquid nitrogen until enzyme analyses were completed. The results of the enzyme analyses are shown in Table 1. There were no significant differences between enzyme activity at SL and HA (Student t test). Thus while changes in skeletal muscle glycolytic or oxidative capacity cannot be entirely eliminated as causal factors, other mechanisms (e.g., allosteric modulation or fiber type recruitment patterns) must be investigated to account for the changes in substrate utilization associated with chronic HA exposure.

TABLE 1

Human skeletal muscle enzymes at SL and at HA  
after 18 days continuous residence

Enzyme	Activity, $\mu$ Moles $\cdot$ Min <sup>-1</sup> G Wet Tissue <sup>-1</sup>		
	Sea Level	High Altitude	P
Lactate Dehydrogenase	186.60 $\pm$ 24.29	170.46 $\pm$ 19.87	> .40
Malate Dehydrogenase	55.39 $\pm$ 5.08	60.07 $\pm$ 4.90	> .30
Glycogen Phosphorylase	6.63 $\pm$ 0.76	6.07 $\pm$ 0.62	> .30
Hexokinase	1.99 $\pm$ 0.11	2.37 $\pm$ 0.27	> .10

Values are mean  $\pm$  SE of samples collected at sea level and after 18 days at 4,300 m.

N = 5 male, sea-level natives.

The next series of experiments attempted to determine the effect of short-term HA residence on the anaerobic threshold (AT). AT has been defined as the exercise intensity, or corresponding  $\dot{V}O_2$ , just preceding the unbalancing of the oxygen demand-supply relationship such that increased anaerobic metabolism is required to satisfy the total energy cost of the work (4). The specific physiological determinant of AT is not agreed upon, and the existence of an

exact threshold of anaerobiosis is also argued. However, by relating the rate of appearance of lactic acid in the blood to the exercise intensity (in terms of percent of maximal oxygen uptake) an estimate of the subject's capacity to work aerobically is obtained. Eight healthy, young soldiers native to SL performed a progressive exercise test at SL, on days 3 and 17 of residence at 4,300 meters, and 5 days after return to SL. In these tests, the subject cycled continuously starting at 0 watts and intensity was increased 23 watts every 3 minutes until the subject could no longer continue. Venous blood was drawn during the last 30 seconds of each increment and respiratory exchange was measured each minute using an automated system. In none of these tests was there an identifiable "threshold" of exercise intensity after which blood lactate concentration began to increase. Rather blood lactate began to increase with the onset of exercise and rose as exercise intensity was progressively increased. The results of the study indicate that acute (day 3) HA exposure had no effect on the relationship between relative exercise intensity ( $\% \dot{V}O_2 \text{ max}$ ) and blood lactate accumulation. Furthermore, while blood lactate accumulation during progressive exercise was attenuated on day 17 at HA as compared to day 3, there was no difference in blood lactate accumulation at SL between pre- and post-sojourn.

Whereas alkalosis is known to enhance endurance performance, acidosis causes an impairment (5). Since short-term high altitude residence is associated with increased endurance for a given relative intensity, it was hypothesized that an adaptation in intramuscular pH regulation may be a causal factor. Five SL residents performed cycle exercise of the same absolute intensity at 50 meters and at 4,300 meters after 15 days continuous residence.  $\dot{V}O_2$  during exercise (mean  $\pm$  SE) was  $3.16 \pm .26 \text{ l} \cdot \text{min}^{-1}$  at SL and was not different at HA ( $3.05 \pm .21$ ). Before and immediately after exercise, venous blood and vastus lateralis muscle were obtained from each subject for determination of serum lactate (LAC) and intramuscular pH. The subjects were instructed to exercise exactly 30 minutes and all but one could complete the entire bout at SL. However, at HA, none could continue to 30 min, and time to exhaustion was  $11.9 \pm 1.6 \text{ min}$ . Resting muscle pH at SL ( $7.10 \pm .02$ ) was not different from HA ( $7.01 \pm .02$ ). There was a greater ( $p < .025$ ) fall in pH following exercise at SL ( $.39 \pm .03 \text{ units}$ ) than at HA ( $.14 \pm .08$ ). The increase in LAC following exercise was greater ( $p < .025$ ) at SL ( $8.80 \pm .81 \text{ m mole} \cdot \text{l}^{-1}$ ) than at HA ( $4.83 \pm .81$ ). These results indicate that for a given absolute intensity the glycolytic contribution to the energy requirement is reduced at HA, thereby reducing performance.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD FORM 1498 1 MAR 68	
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10. NO. CODES*	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER		WORK UNIT NUMBER	
A. PRIMARY	62777A	3E162777A879		BD		127	
B. CONTRIBUTING							
C. CONTINUING	STOG 80-7.2;4						
11. TITLE (Precede with Security Classification Code)* (U)Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 016200 Stress Physiology; 013400 Psychology; 011700 Operations Research							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
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17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		19. PROFESSIONAL MAN YRS	
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ADDRESS* NATICK, MA 01760				ADDRESS* NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME* PANDOLF, KENT B., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4832			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: SAWKA, MICHAEL, N., Ph.D.			
				NAME: POC:DA			
22. KEYWORDS (Precede EACH with Security Classification Code) (U)Environmental Tolerance; (U)Performance Limits; (U)Energy Expenditure; (U)Terrain Coefficients; (U)Dehydration; (U) Human Volunteer							
23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) Develop and validate by physiological studies, mathematical models which synthesize information on military task requirements; the interaction between man, his clothing and equipment, with the environment; to predict mission performance capability identifying areas where additional information is needed.</p> <p>24. (U) Predictive models of heat production and loss, subjective sensation, and limiting criteria in terms of maximum work capacity as well as unsafe levels of extremity temperature and/or body heat content are evaluated. Systems for predicting individual comfort and unit mission performance decrements and tolerance time are developed from these models. Results are validated in chamber and field trials, involving human volunteers as subjects, to guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.</p> <p>25. (U)81 10 - 82 09 Studies involving the energy cost of arm work, and the associated temperature regulating responses, have been conducted to enable expansion of our tolerance/performance prediction model to deal with manual material handling tasks such as ammunition handling and artillery loading. The sustained work levels predicted for fit versus less fit troops, and for male versus female soldiers, have been examined for incorporation into our on-foot mobility model and the costs of downhill marching have been evaluated. The extent to which the mind could reduce the actual energy cost of a light work task has also been explored. The scope of our prediction model's capabilities have been expanded to include sweat rate, and the effects of the associated dehydration and drinking water required to offset it have been investigated. A study has examined the effects of heat acclimatization, environmental condition and subject gender on an individual's ability to perform work when dehydrated. Progress has also been made on predicting the additional stress of working in full sun on troop operations in the field. In addition, three methods of auxiliary cooling have been compared under a variety of environmental conditions.</p>							

\*Available to contractors upon originator's approval

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: The Effect of Physical Training in Air or Water on Heat Tolerance

Investigators: Barbara A. Avellini, Ph.D., Yair Shapiro, M.D., Kent B. Pandolf, Ph.D. and Suzanne M. Fortney, Ph.D.

Background:

A controversy has arisen in past years regarding the role physical conditioning plays in the attainment and retention of heat acclimation. Physical training would be thought to confer some degree of heat tolerance since physiological changes associated with training are similar to those found during heat acclimation.

The improvement of the functional capacity of the cardiovascular system with training is an important aspect in the enhanced heat tolerance of trained individuals. Training stimulates an increase in blood volume which results in an increased stroke volume at the same cardiac output. It appears that athletes are able to maintain an adequate cardiac output sufficient to meet the combined metabolic and heat dissipating requirements for a longer period of time than can non-athletes (1,2). With a higher stroke volume and lower heart rate, more highly trained individuals will be working at a lower percentage of their heart rate reserve when the strain of high ambient temperatures is added to their physical activity.

While an increase in sweat rate (SR) is postulated to be a primary outcome of heat acclimation, the SRs of trained individuals are not necessarily higher than those of untrained controls (1, 2, 4, 6, 7). However, more fit individuals may have a sweat mechanism which is more sensitive to changes in core temperature than less fit individuals. Thus, for a given sweat rate (and provided free evaporation), the internal temperature of athletes would not rise to as high a level as non-athletes.

it seems reasonable to assume that individuals who achieve their high level of aerobic fitness through swimming would not demonstrate enhanced tolerance to heat since their training in cool water does not produce elevated core temperatures and thus does not stimulate the sweat glands. Indeed, some evidence exists to support the contention. Swimmers did not demonstrate the "preacclimatization" to heat which was evident in long distance runners (5). Swimmers also showed both a longer latent period before thermal sweating was initiated and a significantly lower sweat rate throughout a heat exposure (3).

#### Progress:

A detailed report of the findings from this study was presented in a previous annual progress report. It was concluded that physical training can improve the cardiovascular response to an acute dry heat exposure without affecting the thermoregulatory capacity of the body. It appears that training can enhance heat tolerance only if body temperature is permitted to rise during exercise, thus stimulating the temperature-regulating centers for heat dissipation.

During FY 82, two additional reports involving the physical training aspects of the study (European Journal of Applied Physiology) and heat stress responses from the various types of physical training (Journal of Applied Physiology) were accepted for publication.

#### Presentations:

1. Avellini, B. A., Y. Shapiro and K. B. Pandolf. The effect of physical training in air or water on heat tolerance. Presented at the 20th Annual Brouha Work Physiology Symposium, Cambridge, MA, September 1980.
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2. Avellini, B.A., Y. Shapiro, S.M. Fortney and K.B. Pandolf. Effects on heat tolerance of physical training in water and on land. *J. Appl. Physiol.* 53:1291-1298, 1982.
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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Comparison of Thermal Dehydration Effects in Men and Women

Investigators: Michael N. Sawka, Ph.D., Kent B. Pandolf, Ph.D., Michael M. Toner, CPT, MSC, Ph.D., Nancy A. Pimental, M.S., Leslie Levine, M.S., Bruce S. Cadarette, M.S., Michael Foley, B.S. and Leander A. Stroschein, B.A.

Background:

Exercise performance in a hot environment has been shown to be primarily affected by aerobic fitness, state of acclimation, and level of hydration. Both the singular and interactive effects of aerobic fitness and state of acclimation have previously been described in detail. Numerous investigations have also examined the effect of hypohydration on physiological responses to exercise in the heat. These investigations have demonstrated that in comparison to euhydration, hypohydration results in an increased heart rate and core temperature during exercise. Previous investigations have not considered the interactive effect of hypohydration and state of acclimation during exercise in the heat. In addition, relatively few investigations have examined the effects of hypohydration on females during exercise in a hot or a comfortable environment. In fact, direct comparisons between the genders for physiological responses to hypohydration during exercise have been performed on a total of six subjects unmatched for maximal aerobic power. In order to examine possible gender differences during exercise in the heat, the subject populations should be matched for maximal aerobic power.

The purpose of the present investigation was to examine the effects of heat acclimation and subject gender on physiological responses to exercise during hypohydration. These factors were examined in a comfortable, a hot-dry and a hot-wet environment in a group of men and women matched for maximal aerobic power and percent body fat.

### Progress:

All testing was conducted in Natick, Massachusetts during the late winter and early spring months (January - April) when six male and six female subjects were naturally unacclimated to heat. Prior to experimental testing, each subject's percent body fat was determined by underwater weighing and maximal aerobic power was determined by a treadmill running test. In addition, during the three weeks prior to the first heat exposure and throughout the study, nude body weights were measured in the morning after voiding before breakfast. These daily body weights were used to establish baseline body weights.

Subjects attempted to complete two experimental tests in a hot-wet ( $T_a = 35^{\circ}\text{C}$ ,  $rh = 79\%$ ), hot-dry ( $T_a = 49^{\circ}\text{C}$ ,  $rh = 20\%$ ), and comfortable ( $T_a = 20^{\circ}\text{C}$ ,  $rh = 40\%$ ) environment; once when euhydrated and once when hypohydrated. These six experimental tests were repeated both before and after heat acclimation. During the pre-acclimation period, subjects were exposed to heat only one time per week to diminish the effects of acclimation. Each of these experimental tests was 140 minutes (4 repeats of 10 min rest, 25 min exercise). During exercise, subjects walked on a level treadmill at  $1.34 \text{ m} \cdot \text{s}^{-1}$ , and during the rest periods subjects were weighed and rehydrated with tap water to maintain desired body weight (either baseline or  $-5.0\%$  from baseline).

Approximately 24 hours prior to the hypohydration tests, subjects initiated a program of voluntary dehydration. Also on the afternoon prior to the hypohydration tests, subjects performed light exercise in a hot ( $T_a = 38^{\circ}\text{C}$ ,  $rh = 20\%$ ) environment to dehydrate to their target body weight ( $-5.0\%$  from baseline). After achieving target body weight, subjects were removed to a comfortable environment to spend the night under supervision. The following morning, subjects were awakened (0600 h), provided with a light breakfast and tested (0800 h). The euhydration experimental tests were conducted at 1030 h.

The men and women were concurrently acclimated for 10 consecutive days by walking on a level treadmill at  $1.34 \text{ m} \cdot \text{s}^{-1}$  for two 50-minute exercise bouts that were spaced by a 10-minute rest period. During this acclimation program, the environmental conditions of hot-wet and hot-dry were alternated.

Gender effect. In general, significant differences were not found between the genders for final rectal temperature ( $T_{re}$ ), final mean skin temperature ( $T_{sk}$ ), or final heart rate (HR) values during exercise in each of the

conditions. When gender differences were not established for a particular response, the data were combined for subsequent statistical analyses comparing the eu- to hypohydration responses and the pre- to post-acclimation responses. In all cases, when separate analyses were performed for men and women, similar results were obtained. Therefore, data were combined for the subsequent statistical analyses.

Comfortable Environment. Hypohydration increased ( $p < 0.05$ )  $T_{re}$  responses by  $0.30^{\circ}\text{C}$  above euhydration levels during the pre-acclimation test; however, post-acclimation there were no differences between the two hydration states. Heat acclimation decreased ( $p < 0.05$ )  $T_{re}$  responses by  $0.19^{\circ}\text{C}$  during the hypohydration experiments. Hypohydration increased ( $p < 0.05$ )  $\bar{T}_{sk}$  by  $1.57^{\circ}\text{C}$  during the pre-acclimation test; however, post-acclimation, no differences in  $\bar{T}_{sk}$  were observed between the two hydration states. Heat acclimation did not alter  $\bar{T}_{sk}$  responses in the hypohydration experiments. Hypohydration decreased ( $p < 0.01$ ) total body sweat rate ( $\dot{m}_{sw}$ ) values by  $33 \text{ g} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$  and  $67 \text{ g} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$  during the pre- and post-acclimation tests, respectively. Heat acclimation did not alter  $\dot{m}_{sw}$  values in the hypohydration experiments. Hypohydration increased ( $p < 0.01$ ) HR responses by  $19 \text{ b} \cdot \text{min}^{-1}$  above euhydration levels during the pre-acclimation tests; however, post-acclimation there were no differences observed. Heat acclimation decreased ( $p < 0.01$ ) HR by  $13 \text{ b} \cdot \text{min}^{-1}$  during the hypohydration experiments.

Hot-dry environment. Hypohydration increased  $T_{re}$  responses by  $0.46^{\circ}\text{C}$  ( $p < 0.05$ ) and  $0.83^{\circ}\text{C}$  ( $p < 0.01$ ) above euhydration levels during the pre- and post-acclimation tests, respectively. Heat acclimation did not alter  $T_{re}$  responses during the hypohydration experiments. The  $\bar{T}_{sk}$  responses were not altered by level of hydration or state of acclimation. Hypohydration reduced ( $p < 0.01$ )  $\dot{m}_{sw}$  values by  $65 \text{ g} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$  during the pre-acclimation test; post-acclimation no differences in  $\dot{m}_{sw}$  values were observed between the two hydration states. Heat acclimation did not alter  $\dot{m}_{sw}$  values in the hypohydration experiments. Hypohydration increased HR responses by  $13 \text{ b} \cdot \text{min}^{-1}$  ( $p < 0.10$ ) and  $16 \text{ b} \cdot \text{min}^{-1}$  ( $p < 0.01$ ) during the pre- and post-acclimation tests, respectively. Heat acclimation decreased HR responses by  $21 \text{ b} \cdot \text{min}^{-1}$  ( $p < 0.01$ ) during the hypohydration experiments.

Hot-wet environment. Hypohydration increased  $T_{re}$  responses by  $0.46^{\circ}\text{C}$  ( $p < 0.05$ ) and  $0.54^{\circ}\text{C}$  ( $p < 0.01$ ) above euhydration levels during the pre- and post-acclimation tests, respectively. Heat acclimation did not alter  $T_{re}$  responses

during the hypohydration experiments. The  $\bar{T}_{sk}$  responses were not altered by level of hydration or state of acclimation. No differences in  $\dot{m}_{sw}$  values were observed between the two hydration states during the pre-acclimation test. However, hypohydration decreased ( $p < 0.01$ )  $\dot{m}_{sw}$  values by  $102 \text{ g} \cdot \text{m}^{-2} \cdot \text{h}^{-1}$  during the post-acclimation test. Heat acclimation did not alter  $\dot{m}_{sw}$  values for the hypohydration experiments. Hypohydration increased ( $p < 0.05$ ) HR responses by  $19 \text{ b} \cdot \text{min}^{-1}$  during the pre-acclimation test, but post-acclimation did not alter HR responses. Heat acclimation decreased HR responses by  $21 \text{ b} \cdot \text{min}^{-1}$  ( $p < 0.01$ ) during the hypohydration experiments.

The present investigation's data indicate three new findings: (a) that men and women respond in a physiologically similar manner to hypohydration during exercise, (b) when subjects are hypohydrated, heat acclimation decreases thermoregulatory and cardiovascular strain in a comfortable environment, but only decreases cardiovascular strain in hot environments, and (c) post-acclimation the hypohydration responses are less severe in comfortable than hot environments.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Role of Dehydration in Limiting Human Performance While  
Working in the Heat

Investigators: Kent B. Pandolf, Ph.D., Baruch Givoni, Ph.D. and Ralph F.  
Goldman, Ph.D.

Background:

Approximately six years ago, an investigation was conducted to study the acute phase of dehydration which is characteristic of a military operation in hot environments. Predictive modeling of the effects of dehydration for important physiological performance parameters, such as rectal temperature ( $T_{re}$ ) and heart rate (HR) was, to our knowledge, nonexistent. Thus, the purpose of this investigation was to derive predictive formulas for rectal temperature and heart rate considering human performance of exercise in the heat.

Progress:

The technique for induction of dehydration was to define a characteristic morning weight for each of the 16 subjects by weighing over a period of four or five days before the start of the study. This established a "baseline" weight for each individual subject. Subjects were then brought into the laboratory and acclimated by walking in the heat at  $1.34 \text{ m} \cdot \text{s}^{-1}$  for two 50-minute periods separated by a 10-minute rest at  $49^{\circ}\text{C}$ , 20% rh. State of hydration was altered by having the subjects report to the Climatic Chamber at 2200 hours each evening and "rest" at  $49^{\circ}\text{C}$  20% rh while withholding, allowing or encouraging water intake until the desired target dehydration was approached. At approximately 0300 hours each morning, subjects were weighed and transferred to a comfortable room to sleep. At 0700 hours all men were weighed, state of

dehydration estimated, and given a light standard breakfast with fluid adjustment appropriate to the target dehydration individually attempted.

Target hydration levels of 0, -3 and -5% of baseline were evaluated during rest or walking at  $1.34 \text{ m} \cdot \text{s}^{-1}$ , 0 and 5% grade, at  $54^{\circ}\text{C}$ , 10% rh;  $49^{\circ}\text{C}$ , 20% rh;  $35^{\circ}\text{C}$ , 24% rh;  $48^{\circ}\text{C}$ , 72% rh and  $25^{\circ}\text{C}$ , 84% rh. Exposure time totaled 110 minutes: exercise involved two 50-minute walking periods with a 10 minute intervening rest. Rectal temperature and mean weighted skin temperature were recorded continuously and HR checked periodically. The individual level of dehydration was maintained throughout the exposure by administration of water in amounts determined from the acclimatization days as adequate to maintain body hydration at the initial level. Subjects were studied only two days per week, allowing 48 hours between exposures for full recovery of hydration and restful sleep. Thus, we evaluated three levels of metabolic rate and a wide variety of air temperatures and levels of humidity at three levels of hydration.

From the analysis of the experimental data described above, it was possible to express the effect of dehydration as proportional to the final elevation in the rectal temperature of hydrated individuals exposed to similar environments and work levels. The effects of the level of dehydration on rectal temperature are a faster rate of elevation and, therefore, a higher final level where the duration of exposure was limited; however, the final equilibrium temperature, if established, appears to be no higher than without dehydration at these levels. Formulas previously published for predicting rectal temperature (1) were modified using an exponent containing both a dimensionless constant and the level of dehydration in percent. Previously published predictive formulas for HR (2) were also modified to include a dimensionless constant which considered percent dehydration.

During rest, dehydration was found not to alter  $T_{re}$ . Predictive formulas (modified from J. Appl. Physiol. 32:812, 1972) at any time (t) and final  $T_{re}$  ( $T_{ref}$ ) and the time pattern of change during work ( $T_{rew}$ ) and recovery ( $T_{rer}$ ) are:

$$T_{ref} = 36.75 + 0.004(M - W_{ex}) + (0.0128 \text{ clo}^{-1})(T_a - 36) + 0.8e^{0.0047(E_{req} - E_{max})} e^{0.01D}$$

$$\text{Work: } T_{ref} = T_{reo} + (T_{ref} - T_{reo}) [1 - e^{-k(t - t_d)}(1 + 0.1D)]$$

$$\text{Rec: } T_{ret} = T_{rew} - (T_{rew} - T_{rer}) [1 - e^{-\alpha(t - t_{drec})} e^{-0.07D}]$$

where: D = % dehydration; op cit for other terms. A preliminary formula, which predicts heart rate considering dehydration is:

$$I_{HR(\text{Dehyd})} = 25 + (I_{HR} - 25)(1 + 0.06D)$$

Using this  $I_{HR}$  for dehydration, final HR, and HR at time t, are computed as previously published (J. Appl. Physiol. 34:201, 1973).

This predictive capacity to consider state of hydration has been tentatively added to our model which predicts military performance capacity and the occurrence of heat stress and/or heat casualties during military operations.

The tentative coefficients developed from these experiments resulted in only a minor adjustment to the original predictive formulas. However, these coefficients were derived from only one group of test subjects and somewhat limited work and environmental conditions. An entirely different group of test subjects need to be evaluated to validate the coefficients derived from previous dehydration experiments. The validation study will involve 8-16 acclimatized subjects, two levels of hydration (0 and -5%), one level of physical work (300 watts) and two environmental conditions ( $35^{\circ}$ ,  $49^{\circ}$ C). We also plan to compare physiological responses of men and women to dehydration both before and after being heat acclimatized.

While no additional data was collected during FY 81, Dr. Baruch Givoni (visiting scientist, Ben Gurion University of the Negev, Israel) has suggested further refinements concerning the coefficients for prediction equations pertaining to state of hydration and also some further potential validating studies. These validation studies have been conducted during FY 82 and the methodology and results are presented in this annual report under another study title. Those data will be computer modeled with the data of the present protocol. Finishing that study has completed this project.

#### Presentations:

1. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule, and R. F. Goldman. Effects of dehydration on predicted rectal temperature and heart rate during work in the heat. Med. Sci. Sports 9:51-52, 1977.
2. Pandolf, K. B., R. L. Burse, B. Givoni, R. G. Soule, and R. F. Goldman. Predicting rectal temperature and heart rate responses to dehydration while working in the heat. XXVIIth International Congress of Physiological Sciences (Programme), 12-21, 1977.

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2. Givoni, B. and R.F. Goldman. Predicting heart rate response to work, environment, and clothing. *J. Appl. Physiol.* 34:201-204, 1973.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Additive Effects of Solar and Metabolic Heat Load in Predicting Heat Intolerance

Investigators: Kent B. Pandolf, Ph.D., Yair Shapiro, M.D., Baruch Givoni, Ph.D., Fred R. Winsmann, M.S., John R. Breckenridge and Ralph F. Goldman, Ph.D.

Background:

The solar radiant environment, as a function of the particular geographic region, hazy or clear sky, cloud cover, terrain cover and albedo, time of day and solar elevation, is an important consideration for military operations in hot environments. This Division has developed methods of prediction for the actual solar heat load arriving at the skin in lightly clothed men (1) and more heavily clothed men (2). However, these studies have been of a theoretical physical nature, validated by direct measurement on heated, sweating copper manikins.

Although we have been able to develop the ability to predict rectal temperature and heart rate responses to work, environment and clothing (3,4), further refinement of our predictive capabilities is seen to be necessary. This study evaluated the decrement in tolerance time or performance to work and rest in the heat as affected by a simulated ambient solar heat load. The results of these experiments should provide adequate data for integrating the metabolic responses of solar and metabolic heat and enable us to predict more accurately the soldier's responses to operational combat clothing and equipment during actual field situations in hot environments.

We have completed the first in a series of experiments involving the effects of solar radiant environment on soldier's performance to work or rest in the heat. Initially, 24 subjects were acclimatized to heat walking in shorts at  $1.34 \text{ m} \cdot \text{s}^{-1}$  for two 50-minute periods separated by 10-minutes rest at  $49^{\circ}\text{C}$ , 20% rh. After six days of acclimatization, the 24 subjects were divided into

three groups of eight for experimental evaluations during either rest, walking at  $1.34 \text{ m} \cdot \text{s}^{-1}$ , or walking  $1.34 \text{ m} \cdot \text{s}^{-1}$  at a 5% grade. A bank of 72 infrared 350 watt lamps were secured at near ceiling height in the NLABS Tropical Environmental Chamber. This bank of lights simulated approximately 90% of a typical, severe solar heat load. Subjects were evaluated during rest or walking ( $1.34 \text{ m} \cdot \text{s}^{-1}$ , 0 or 5% grade), at  $40^{\circ}\text{C}$ , 32% rh and  $35^{\circ}\text{C}$ , 75% rh with and without the solar radiant load while wearing either shorts, socks and sneakers, or the combat tropical uniform. The proposed experimental duration was a total of two hours (10 minute rest, 50 minute work, 10 minute rest, 50 minute work). During these experiments water was administered ad libitum while air motion was constant at approximately  $0.5 \text{ m} \cdot \text{s}^{-1}$ .

#### Progress:

As part of this same study, but for validative purposes, other individual blocks of experimentation will be conducted in the future. The first series of experiments that are planned to be conducted will evaluate the physiological responses of two different radiant heat loads, three different wind speeds and three different clothing ensembles at  $40^{\circ}\text{C}$ , 20% rh in 10 male soldiers prior to heat acclimatization. Half of these soldiers will be acclimated to heat with a solar radiant load while the other half will be acclimated to heat without solar load. All subjects will be re-exposed to all of the environmental conditions outlined above.

#### Presentation:

Pandolf, K. B., Y. Shapiro, J. R. Breckenridge and R. F. Goldman. Effects of solar heat load on physical performance at rest and work in the heat. Fed. Proc. 38:1052, 1979.

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Program Element; 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Comparative Methods of Auxiliary Cooling in Man

Investigators: Yair Shapiro, M.D., Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Less energy is needed to cool a man by cooling his microclimate than by cooling the macroclimate. As an auxiliary cooling method, it has been proven that it is much more effective to use water suits or ice suits than to use a cool air suit. The main problem remaining unsolved is the control of the cooling rate. The most advanced control system was developed by Webb and colleagues (1). This system receives input from the subject's oxygen uptake and skin temperature and the resultant output is the water temperature of the suit. This control mechanism is very expensive and complicated and not applicable for general use. In Japan and in the gold mines of South Africa, they use ice suits (dry ice in Japan and water ice in S.A.). It appears that these suits and especially the water ice variety, are very effective during high work loads in very hot environments. However, the direct contact of the cold surface with the skin is unpleasant and may induce local cold injury (especially with dry ice suits).

We suggest that if the ice in the suit is replaced with materials which melt at a temperature closer to the skin temperature, the skin itself will be the regulator and control mechanism of the cooling rate.

Exposure to cold produces peripheral vasoconstriction and a decreased skin temperature. Thus, the temperature gradient from skin to suit decreases and becomes closer to zero. When the body accumulates heat, the peripheral blood vessels vasodilate and the skin becomes warmer. Thus, the temperature gradient from skin to suit becomes greater and the heat transferred between the body and

the suit will be greater. Potentially, there are two problems with this concept: (a) the material substituted for ice has to be nontoxic and (b) it has to have a high latent heat of fusion, as close as possible to that of water. We know of two nontoxic materials: (a)  $\text{CaCl}_2 \cdot 6\text{H}_2\text{O}$  and (b) acetic acid; the first one melts at  $24.4^\circ\text{C}$  and the second at  $16.6^\circ\text{C}$ , but the latent heat of both of them is 50-55% of water. Thus, the total "cold content" of such suits will be about half of that of water, or for the same effect, the suit would have to be twice as heavy. The problem can be solved by developing a two layer cooling suit; the inner layer - high melting point - thin and close to the skin, and the other - one of ice - thicker than the inner one. The aim of this study is to develop an effective and safe auxiliary cooling suit for man.

Progress:

We are experiencing a great deal of difficulty in securing the appropriate cooling suits to be evaluated under this protocol. However, another protocol involving auxiliary cooling was completed this FY and is reported under another study title.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Physiological Evaluation of the Temperate Battle Dress  
Uniform (TBDU)

Investigators: Fred R. Winsmann, M.S., Ralph F. Goldman, Ph.D.,  
Lawrence Drolet, M.S. and Kent B. Pandolf, Ph.D.

Background:

Based on adverse comments in the field regarding the Temperate Battle Dress Uniform (TBDU) and its "heat stress potential" in particular, a physiological evaluation of this uniform was requested by Director, Individual Protection Laboratory, NLABS.

The TBDU had not been previously evaluated in a controlled human climatic chamber study, nor had evaluations using the heated/sweating copper manikin been carried out. The developer had felt that, since the cut and material was identical to that of the Desert Battle Dress Uniform, additional testing was not necessary. However, as a result of the questions raised in the field, biophysical (i.e., copper manikin) values were obtained on the TBDU and its counterpart systems for hot weather use (i.e., Desert BDU, Tropical OG-107 and Tropical Camouflage). Biophysical values were also obtained on the Durable Press Utility Fatigue Uniform (DPU) for comparison of all hot weather Army combat clothing systems.

Progress:

In general, the extra layers of material added to the TBDU to enable it to provide the extra warmth requested in the Required Operational Capability (ROC) under which the TBDU was developed, did not add significant extra insulation or significantly reduce the moisture vapor permeability of the TBDU when measured in a low air motion environment. In essence, as our work has

consistently demonstrated over the years, the cut of the uniform and the resulting air layers trapped between the skin and the uniform, plus the external air layer, essentially control the insulation of the system; there is relatively little input from the fabric per se. Differences in insulation could be demonstrated in wind studies as a function of altered air penetration in those uniforms with extra layers, or additional pocket coverage. Similarly, moisture vapor permeability would not be altered, except in relation to changes in insulation, but material with extra layers, double pockets and direct contact with the skin would produce sensations of increased dampness and clamminess when worn in a hot environment by sweaty subjects. We decided that human study data should be obtained as soon as possible. Such data, it was suggested, would support the position that while the TBDU would, in fact, feel somewhat hotter, there was relatively little, if any, real difference in heat stress among the TBDU and its three counterpart systems.

Climatic chamber conditions were selected by computer modeling analysis of the different uniform ensembles, using estimated pumping coefficients (a parameter which characterizes the change in insulation and permeability with air or subject motion). This procedure enabled us to select conditions which would provide the greatest probability of differentiating between the four uniforms proposed for study: the Temperate Battle Dress Uniform (TBDU), the Durable Press Utility Uniform OG-507 (DPU), the Hot Weather Camouflage Tropical Uniform (TC Marine) and the Hot Weather Combat Coat and Trousers, OG-107 (OG HW). The computer analysis indicated that there would be no meaningful physiological differences and that, at best, it might be possible to differentiate the uniforms in terms of sweat evaporation to production (E/P) ratio. This is determined from changes in the subjects' clothed body weights before and after the hot chamber exposure (i.e., sweat evaporation), divided by changes in nude body weights before and after the exposure (i.e., sweat production). All weights are adjusted for water intake and any urinary or other outputs. The test conditions selected were 85°F, 70% RH, with a full solar load (ranging from 60 to 80 watts depending on an individual's position on the treadmill). Eight volunteer subjects participated in this study (four male and four female).

Based on the assumed pumping coefficients and computer modeling, a wind speed of five mph was initially selected and used on the first day of the five-day study period, which was a practice training acclimation day. However, during the first day the subjective perceptions of discomfort were sufficiently minimized by the wind that we decided to reduce the wind speed to three mph.

This would emphasize the subjective sensation differences, although perhaps diminishing slightly the chances for seeing physiological differences. The prediction model had suggested that the chances of seeing any physiological difference would be slight even at five mph wind velocity. Most probably such differences would be in sweat evaporation to sweat production ratio (E/P ratio), and this would not be dramatically affected by dropping from five to three mph wind speed. The predicted physiological differences would be in the skin temperatures measured during the first 15 or 20 minutes following the work period, and any such differences would have been practically meaningless even if demonstrably different.

On all days, each of the four uniforms was worn by one man and one woman (eight subjects), with a modified Latin square design so that each uniform was worn by each subject and the order of presentation of the different uniforms was balanced. Each day was initiated with a one-hour rest period in the heat, a 50-min walk at three mph under the solar lights, and a subsequent one-hour rest. The usual measurements for this type study were taken (i.e., rectal and skin temperature, heart rate, subjective questionnaires).

As expected, the most impressive difference was in the E/P ratios of the various uniforms. Troops wearing the camouflage version of the Tropical Combat Uniform (TC Marine) were able to evaporate 85% of the sweat they produced; wearing the Durable Press Utility Uniform (DPU) they were able to evaporate 82%; with the Hot Weather Combat Uniform (OG HW), they were able to evaporate 79%; none of these three differed significantly or even approached statistically significant differences. However, when the Temperate Battle Dress Uniform (TBDU) was worn, only 71% of the sweat produced was able to be evaporated and the difference, although greater than the 5% level of probability, produced an F value for group differences of 2.3 suggesting that with a larger sample size, or less individual variability, a significant difference might have been developed between the TBDU and all other uniforms. There were no significant differences or meaningful trends in rectal temperature, mean weighted skin temperature or heart rate between any of the uniforms.

The subjects were queried as to their perception of the difficulty of walking while wearing the different uniforms each day, and there were no differences in rated perceived exertions. A thermal sensation scale was also administered and, again, there was no difference in uniforms. A final debriefing questionnaire was administered and five of the eight test subjects felt that the

TBDU did not "release the heat" or "felt too hot", while an additional subject did not care for the fit of the TBDU. All eight subjects indicated preference towards the Camouflage Tropical Combat Uniform (TC Marine).

In summary, the results of this test, for which conditions were selected to maximize the possibility of seeing physiological differences between the systems, failed to reveal major physiological differences, although clearly, as judged from the efficiency of sweat evaporation, the Temperate Battle Dress Uniform with a 71% value required substantially more sweat production per unit of evaporation than did the other uniforms. Why the Camouflage Tropical Combat Uniform (TC Marine) appeared to be significantly preferred and more comfortable than the OG-107 version of the same uniform is puzzling. The following reasons are suggested: either the tailoring done to achieve an acceptable fit for the Tropical Combat Marine Uniform made a significant difference in the relative air layers trapped between the TC 107 and the TC Camouflage Uniforms; or there is actually some difference in the characteristic of the uniform that is modified by the camouflage printing process; or random chance produced the observed differences since they did not reach a significant level.

#### Presentation:

Winsmann, F.R. and R.F. Goldman. Evaluation of the Temperate Battle Dress Uniform (TBDU) in comparison to the Durable Press Utility Uniform (OG-507), Tropical Combat Uniform (OG-107) and Tropical Combat Camouflage Uniform (TC Marine). Report submitted to requester; Director, Individual Protection Laboratory, NLABS, July 1982.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Heat Transfer during Water Immersion: I. Effect of Type  
and Intensity of Exercise

Investigators: Michael M. Toner, CPT, MSC, Ph.D., Nancy A. Pimental,  
M.S., Bruce S. Cadarette, M.S., Michael N. Sawka, Ph.D.,  
Claire Kimbrough, James E. Bogart, B.S. and Kent B.  
Pandolf, Ph.D.

Background:

Limited information has been obtained in the Underwater Support Laboratory on the heat transfer of exercising subjects who are immersed in water. Other laboratories have shown that the heat debt (i.e., the loss of body heat over time) in cold water during exercise is greater than during rest (1,2). Two biophysical factors could account for the greater heat debt during exercise. First, the conduction of heat away from the core to the limbs via the increased circulation of blood to the exercising muscles could account for the higher heat debt. Secondly, movement of the limbs through the water could substantially reduce the insulation afforded by the boundary layer between the skin and the water. Nadel et al. (3) have shown that there is a 2.5 fold reduction in the insulation of the boundary layer during exercise as compared to rest. In addition, these workers have shown that this insulation layer remains unaltered between varied exercise intensities.

The purpose of this study is to obtain information on the heat transfer responses of exercising individuals. Specifically, this investigation examines the interaction of both exercise type and exercise intensity with water immersion.

Progress:

Eight subjects participated in this study and had a mean age, height and weight of 22.4 years, 172.2 cm and 70.9 kg, respectively. The group averaged

13.4% body fat determined by an underwater weighing technique. Exercise was performed on a specially designed arm and leg ergometer. Two Monark cycle ergometers were modified for use in air and in water. The leg ergometer was modified as previously described (4). The arm ergometer was altered by mounting the flywheel directly above the arm crank. Two exercise intensities which elicited metabolic rates of 450 and 680 W were performed by the legs and with the combination of arms and legs. Arm exercise was performed at the low intensity only. All experiments were 60 minutes in duration and were performed in water at 20, 26 and 33°C.

Table 1 presents the final metabolic and thermal responses during exercise in water at 20°C. During low intensity exercise there were no significant differences in the final metabolic rates ( $M$ ) or skin temperatures ( $\bar{T}_{sk}$ ) between the three types of exercise. However, the final rectal temperature ( $T_{re}$ ) for leg (L) exercise was higher ( $p < 0.05$ ) than both arm only (A) or combined arm and leg (AL) exercise; heat flow, though not different ( $p < 0.1$ ), tended to be less in L than A exercise. During high intensity exercise,  $M$  was higher during AL compared to L exercise. The  $\bar{T}_{sk}$  and heat flow values were not different ( $p > 0.05$ ), though  $T_{re}$  showed similar trends as during low intensity exercise.

During low intensity exercise in 26°C water, there were no significant differences ( $p > 0.05$ ) between types for final  $M$  and heat flow. The final  $T_{re}$  responses were higher during L as compared to A and AL ( $p < 0.01$ ) whereas final  $\bar{T}_{sk}$  were higher during both A and AL compared to L ( $p < 0.05$ ). During high intensity exercise in 26°C water, there were no differences ( $p > 0.05$ ) in final  $T_{re}$ ,  $T_{sk}$ ,  $M$ , or heat flow between AL and L. In water at 33°C, responses between types showed identical trends as seen in 26°C during both low and high intensity exercise.

It is evident from these results that the change in rectal temperature is dependent upon the type of exercise performed in cold water. The involvement of the arms in exercise either alone or in combination with the legs decreases rectal temperature to lower values than exercise performed with legs only. These differences may be due to less insulation, shorter conductive heat pathways and/or greater surface area to mass ratios for the arms compared to the legs.

Table 1  
Final Metabolic and Thermal Responses during Arm (A), Leg  
(L) and Combined Arm and Leg (AL) Exercise in Water at 20°C

		Metabolic Rate (W)	Rectal Temp (°C)	Skin Temp (°C)	Heat Flow (W/m <sup>2</sup> )
Low Intensity	A $\bar{X}$	601	36.2	22.1	328
	SD	153	0.5	0.3	85
	AL $\bar{X}$	600	36.2	21.9	294
	SD	150	0.7	0.3	69
	L $\bar{X}$	562	36.6	21.8	282
	SD	136	0.9	0.3	75
	Mean Diff		A, AL < L		
	P	ns	< 0.05	ns	< 0.1
	AL $\bar{X}$	761	36.8	22.2	309
	SD	188	0.6	0.3	79
High Intensity	L $\bar{X}$	653	37.1	21.9	286
	SD	167	0.5	0.5	83
	Mean Diff	AL > L			
	P	< 0.05	< 0.1	ns	ns

ns is not significant

Presentation:

Toner, M.M., N.A. Pimental, C.M. Kimbrough, B.S. Cadarette, M.N. Sawka and K.B. Pandolf. Thermoregulatory responses during arm, leg and combined arm and leg exercise in water at 20, 26 and 33°C. Fed. Proc. 41:1678, 1982.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Heat Transfer during Water Immersion: II. Effect of Body  
Composition and Body Size

Investigators: Michael M. Toner, CPT, MSC, Ph.D., Michael E. Foley, B.S.,  
James E. Bogart, B.S., William L. Holden B.S. and Michael  
N. Sawka, Ph.D.

Background:

Numerous investigations have shown a strong negative relationship between body fat and heat loss during cold stress. Smith and Hanna (1) obtained a high negative correlation between mean skinfold thickness and the lower critical water temperature. The study of Rennie et al. (2) has indicated a positive relationship between subcutaneous fat and maximal tissue insulation during water immersion. Buskirk and colleagues (3) related the percent body fat of individuals to heat debt during a two-hour exposure in 10°C air; while in 15°C air, Baker and Daniels (4) indicated that subcutaneous fat thickness may be more important than percent total body fat.

In contrast to these studies, the heat transfer model developed by Strong, Gee and Goldman (5) indicates that the surface area to mass ratio of an individual is an important factor which influences heat loss in the cold. These investigators argue against the statistical relationships made between body fat and heat loss because of the limited populations used in these studies. In addition, they point out that non-perfused muscle provides more than half the insulation as fat tissue for a given thickness; and therefore, a non-perfused muscle that is twice as thick as a fat layer would provide more resistance to heat loss.

The present study compared the metabolic and thermal responses of two groups of subjects. The groups were matched by body composition, but the differences in body mass of the groups were maximized. Each group was exposed to a range of water temperatures and activity levels.

Progress:

Ten subjects from the Test Subject Platoon at NLABS volunteered and completed the testing procedures. The subjects were divided into two groups according to body mass. The physical description of the groups is shown in Table 1.

TABLE 1

Physical Description of the Small (S) and Large (L) Mass Groups

Group		Height (cm)	Weight (kg)	Lean Body Weight (kg)	Body Fat (%)	Sum of Skinfolds (mm)	Surface Area/ Weight (m <sup>2</sup> /kg x 100)
S	$\bar{X}$	167.5	65.4	54.3	16.9	115.7	2.68
n = 5	SD	4.6	8.8	7.6	3.0	37.4	0.09
L	$\bar{X}$	182.9	83.7	69.8	16.5	128.0	2.46
n = 5	SD	5.7	5.8	4.3	3.0	33.6	0.12
$\Delta$ (L-S)		15.4	18.3	15.5	-0.4	12.3	-0.22
T		4.73	3.87	3.98	0.20	0.55	2.14
P		< 0.01	< 0.01	< 0.01	ns	ns	< 0.10

ns is not significantly different

Experiments in water were performed in 18, 26 and 30°C. Subjects rested and exercised at a moderate intensity (approximately 1.5 l O<sub>2</sub>/min) in each water temperature for a duration of one hour. Skin and rectal temperatures, heat flow, metabolic rate and heart rate were recorded for each subject during all water exposures. All data have been obtained and are being prepared for statistical analysis.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Heat Transfer During Water Immersion: III. Effect of  
Clothing

Investigators: Michael M. Toner, CPT, MSC, Ph.D., Michael E. Foley, B.S.,  
James E. Bogart, B.S. and Darren S. Billings, SP4, B.S.

Background:

Previous studies from this laboratory have investigated the interactions of intensity and type of exercise, subject morphology and water temperature during immersion. The intent of such studies has been to gain insight into the thermal and physiological responses of individuals exposed to cold stress. In addition, these studies support a biophysical program dealing with predictive modeling of heat transfer (1). The support provided by the physiological studies includes both the thermal data used in the model and the identification of additional input variables needed within the model.

The present study is designed to expand the information on heat transfer during water immersion by examining the metabolic and thermal responses of clothed individuals. Earlier work by Bynum et al. (2) studied responses of individuals clothed in diving wet-suits. In this study, subjects were immersed in cold water for one hour. In contrast, the present investigation will study individuals who are clothed in dry-suits and are immersed for a duration of up to three hours. The dry-suit approach will provide a similar microclimate environment as that normally encountered by the soldier in cold air. The major advantage of water in contrast to air is that it provides high heat transfer at temperatures that are within safe limits of possible freezing injuries to the skin.

### Progress:

Twelve subjects from the Test Subject Platoon have volunteered for the study. Body composition of these subjects has been determined by an underwater weighing procedure. Measurements of skinfold thickness have also been obtained.

All sessions are carried out in the Underwater Support Laboratory's 34,000 liter tank. Water temperature can be maintained within  $\pm 0.3^{\circ}\text{C}$  and continuous circulation insures adequate mixing throughout the tank. Subjects will be seated on a chair and immersed to neck level during the experiment. Three clothing ensembles have been provided by the US Naval Coastal Systems Laboratory, Panama City, FL. The ensembles are a dry suit only, dry suit plus light insulative underwear, and dry suit plus heavy underwear. Each subject will wear each ensemble in water at both 10 and 15 $^{\circ}\text{C}$  for a duration of three hours. All experiments are resting. This study is currently in the data collection stage.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Comparison of Eccentric and Concentric Muscle  
Contractions during Various Types of Work

Investigators: Nancy A. Pimental, M.S., Yair Shapiro, M.D. and Kent B.  
Pandolf, Ph.D.

Background:

There is wide variance in the literature concerning the energy expenditure and efficiency of concentric as compared to eccentric exercise (1,2,3). This may be due to the use of different exercise modes in comparing the two types of exercise. In order to clarify the situation, the present study compared exercise while walking uphill and downhill on a treadmill and while cycling concentrically and eccentrically on a bicycle ergometer. Walking downhill backward was also examined because this may be considered the true reverse of walking uphill. A second purpose of this study was to accumulate data for use in evaluating the energy expenditure prediction formula of Pandolf et al. (4), which takes into consideration subject weight, weight of the external load to be carried, walking speed, type of terrain traversed and grade. The formula is used to predict the soldier's metabolic rate for a specified mission. Currently the formula is not capable of handling negative grades, although there is a need for energy expenditure data while walking on a downhill terrain.

Progress:

Seven fit male soldiers (20 yr, 176 cm, 70 kg, 16% body fat) walked on a treadmill at various grades (-15 to + 30%) and speeds (up to  $1.56 \text{ m} \cdot \text{s}^{-1}$ ) carrying loads up to 30 kg. They also performed concentric and eccentric cycling at exercise intensities ranging from 0 to 260 watt. Exercise bouts lasted 20 minutes; oxygen consumption and heart rate were measured at minutes 5-8, 11-14, and 17-20. Regression analyses were performed on heart rate and oxygen

consumption; exercise intensity and oxygen consumption; and, exercise intensity and heart rate for the four types of exercise (uphill walking, concentric cycling, downhill walking, eccentric cycling). Gross exercise efficiencies were calculated by dividing exercise intensity by oxygen consumption. Oxygen consumption values obtained in the present study during level and uphill walking were compared to those values predicted by the formula of Pandolf et al. (4).

At the same oxygen consumption, eccentric cycling elicited the highest heart rate, followed by downhill walking, uphill walking, and concentric cycling (Figure 1). Only the regression line for eccentric cycling had a significantly higher slope than the other three regression lines ( $p < 0.05$ ). Average gross exercise efficiencies for uphill walking and concentric cycling were similar (13.5 and 14.5%), and were significantly different from those for downhill walking (-33.5%) and eccentric cycling (-60.6%). For each type of exercise, absolute efficiency was greater with increasing exercise intensity. Actual energy expenditures for walking uphill and on the level were then compared to predicted values using the formula of Pandolf et al. (4) (Table 1). The formula was found to be accurate for all uphill conditions at  $1.12 \text{ m} \cdot \text{s}^{-1}$ . For walking uphill at  $0.56 \text{ m} \cdot \text{s}^{-1}$ , the formula predicted slightly low (5 to 16%) while the formula underestimated energy expenditure for level walking by 14 to 33%. These findings would imply further modifications to this formula are necessary, particularly to include the observations for downhill walking.

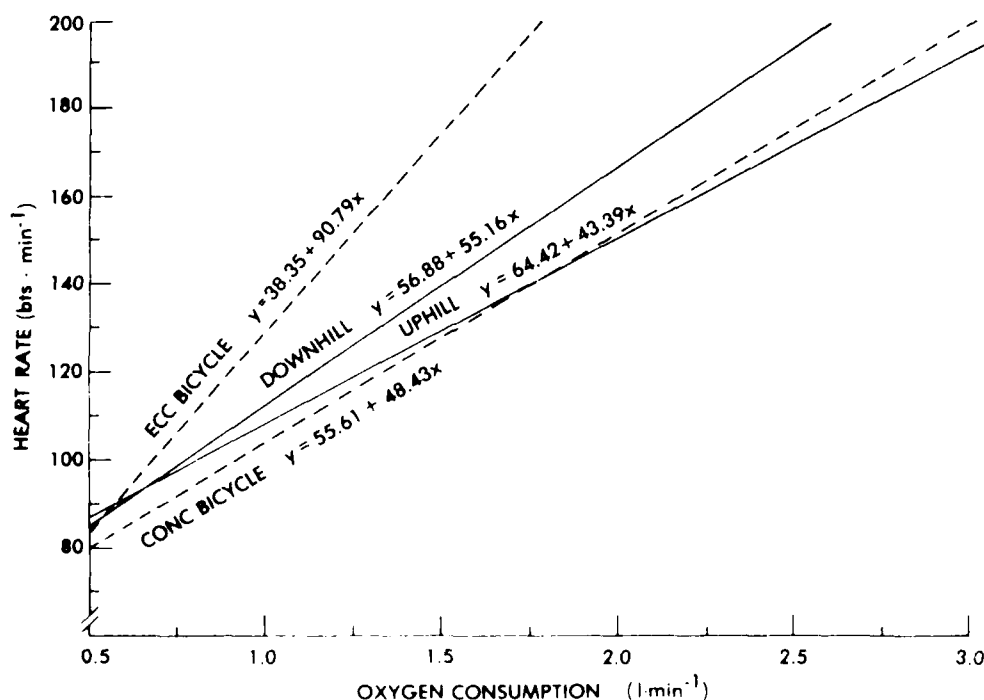


Figure 1. Regression of oxygen consumption and heart rate.

Table 1

Differences between actual and predicted (4)  
energy expenditures while walking on the level and uphill.

SPEED ( $\text{m} \cdot \text{s}^{-1}$ )	GRADE (%)	LOAD (kg)	ACTUAL (watt)	PREDICTED (watt)	DIFFERENCE (%)	SIGNIFICANCE
0.67	+5	0	280	236	16	$p < 0.01$
0.67	+5	15	313	271	13	$p < 0.01$
0.67	+5	30	364	328	10	$p < 0.01$
0.67	+10	0	345	318	8	$p < 0.01$
0.67	+10	15	401	371	7	$p < 0.01$
0.67	+10	30	467	445	5	$p < 0.02$
0.67	+30	0	731	648	11	$p < 0.01$
1.12	+5	0	389	376	3	NS
1.12	+5	15	439	442	-1	NS
1.12	+5	30	529	528	0	NS
1.12	+10	0	511	514	0	NS
1.12	+10	15	595	609	-2	NS
1.12	+10	30	699	725	-4	NS
0.67	0	0	215	153	28	$p < 0.01$
0.67	0	15	255	171	33	$p < 0.01$
1.12	0	0	294	238	18	$p < 0.01$
1.12	0	15	318	274	14	$p < 0.01$

#### Presentations:

1. Pimental, N.A., Y. Shapiro and K.B. Pandolf. Comparison of physiological responses to various types of exercise: uphill and downhill walking and concentric and eccentric cycling. Paper delivered at the 20th Annual Brouha Work Physiology Symposium, Cambridge, Massachusetts, 17-19 September 1980.
2. Pimental, Nancy A., Yair Shapiro and Kent B. Pandolf. Comparison of physiological responses to uphill and downhill walking and concentric and eccentric cycling. Fed. Proc. 40(3):497, 1981.

#### Publication:

Pimental, Nancy A., Yair Shapiro and Kent B. Pandolf. Comparison of uphill and downhill walking and concentric and eccentric cycling. Ergonomics 25(5):373-380, 1982.

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Program Element: 6.27.77A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Metabolic Heat Production ( $\dot{V}O_2$ ;  $\dot{V}CO_2$ ) and endocrine  
levels (insulin; catecholamines) during exercise with and  
without the relaxation response

Investigators: Bruce S. Cadarette, M.S., Leslie Levine, M.S., Margaret A.  
Caudill, M.D., Ilan Kutz, M.D., Herbert Benson, M.D. and  
Ralph F. Goldman, Ph.D.

Background:

Previous research by Benson et al (1) concerning the metabolic responses to exercise while eliciting the relaxation response, indicated a decrease in oxygen uptake ( $\dot{V}O_2$ ) when exercising at a steady state relative to exercising at the same intensity without eliciting the response. However, this research was considered a pilot study with a small number of subjects and with some question about the measurement techniques. Benson's group therefore turned to our laboratory, which has more expertise in measuring human heat production, requesting that we collaborate on a larger study in this area. We accepted the request knowing that it offered a chance to share our experience and also a unique opportunity to examine possible self-induced individual variability in heat production during steady state exercise.

Progress:

Twenty-four volunteers served as subjects for the study. Thirteen were controls who had never elicited the relaxation response and 11 were classified as responders with experience in the technique. All subjects cycled continuously for 40 minutes at 50 watts on an electrically braked cycle ergometer. For analysis purposes data collection was divided into three periods, a 10-minute pre-exposure period, a 20-minute exposure period during which the responders elicited the relaxation response, and a 10-minute post-exposure period.

While on the cycle, two minute expired gas samples were collected into a Tissot gasometer at minutes three and seven of every 10-minute interval throughout exercise. These samples were analyzed for  $\dot{V}O_2$ , respiratory exchange ratio (R), respiratory rate ( $f_r$ ), tidal volume ( $V_T$ ), pulmonary ventilation ( $\dot{V}_E$ ) and the ventilatory equivalent for oxygen ( $\dot{V}_E/\dot{V}O_2$ ). Heart rates were monitored with a Hewlett-Packard telemetry system and values were recorded during the gas collection periods. Prior to exercise, all subjects were catheterized for collection of blood to measure levels of insulin, epinephrine and norepinephrine throughout exercise. During the pre- and post- exposure periods, blood samples as well as measurements of rated perceived exertion (RPE) (2) were taken after each metabolic measurement, but none were taken during the exposure period, only immediately post-exposure. All results were analyzed with a two-way analysis of variance.

Unlike the results of the pilot study, our data showed no significant differences in  $\dot{V}O_2$  between groups throughout the course of exercise. A mean  $\dot{V}O_2$  of 0.79 L/min and 0.77 L/min were shown by the responders and controls. The R also showed no changes between groups throughout the exercise trial, starting out at 0.84 during pre-exposure and rising to 0.87 for the other two measurements. Significant differences were seen between the groups when examining  $f_r$  during the exposure period. While no difference was seen between groups in the pre- or post-exposure period, the responders decreased from 17 to 13.5 breaths per minute between the pre- and exposure intervals, while the controls rose slightly from 17 to 18.5. In response to the decreased  $f_r$  the responders showed an increase in  $V_T$  during the exposure period from 1.2 to 1.5 L/breath. No such increase was seen in the controls and this resulted in a significant difference. There was no difference between the groups pre- or post-exposure. Pulmonary ventilation again showed a significant difference between groups only during the exposure period. The responders at approximately 18 L/min were 2.25 L/min less than the controls during this period. Further, the responders  $\dot{V}_E/\dot{V}O_2$  ratio of 23 was smaller than the controls 26 during the exposure with no difference between groups at other times. Heart rates showed no significant changes with the relaxation response but the groups did remain different throughout the course of exercise with the responders consistently 10 beats/min higher than the controls. Finally, the RPE data showed no significant difference between groups at any time. However, there were within group differences. The responders showed a significantly increased

perception of effort comparing the post-exposure period (11.0) with their pre- (9.6) and exposure (9.7) scores. The controls, however, showed increased values during the exposure (10.6) and post-exposure (11.1) periods relative to the pre-exposure (9.2) interval.

We concluded from our results that, while it did not affect oxygen uptake, elicitation of the relaxation response could modify some of the normal physiological responses to light exercise for an extended period of time. Further, it was clear that these respiratory changes had an effect on the subjects' perception of exercise intensity during the response period. At the present time, a manuscript is under preparation on the results of this study, and Benson's group is preparing to do a further study with our laboratory involving exercise at a higher intensity to see if the changes shown with a very light exercise load can be maintained.

Presentation:

Cadarette, B.S., J.W. Hoffman, M. Caudill, I. Kutz, L. Levine, H. Benson and R.F. Goldman. Effects of the relaxation response on selected cardiorespiratory responses during physical exercise. *Med. Sci. Sports Exercise* 14(2): 127, 1982.

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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Troop Mobility as a Function of Load and Terrain

Study Sub-Title: Prolonged Self-Paced Hard Physical Exercise Comparing Trained and Untrained Men

Investigators: Leslie Levine, M.S., William J. Evans, Ed. D., Fred R. Winsmann, M.S. and Kent B. Pandolf, Ph.D.

Background:

Soldiers are often required to walk at self-paced velocities over a variety of terrains to accomplish an assigned mission. Necessarily, these troops must reach their destinations in as short a time as possible. Previous self-pacing studies by this laboratory have demonstrated that moderately fit males will naturally "select" an energy expenditure of  $\sim 495 \text{ watts} \pm 10\%$  when requested to walk at as fast a pace as possible (2). More recently, in a study comparing voluntary hard work rates of males and females, Evans *et al.* (1) showed that both males and females tend to choose an energy expenditure that corresponds to 45% of their maximum aerobic power ( $\dot{V}O_2 \text{ max}$ ). These authors indicated that the voluntary hard work rate is dependent upon maximal aerobic power.

In these self-pacing studies (1,2,7) subjects walked for 1 to 1-1/2 hours only. However, troop movements may often require a continuous march for extended periods of time. Some recent investigations (3,5) have suggested that well-trained subjects exercising at self-paced intensities for prolonged periods of time may reduce their metabolic output to below 40%  $\dot{V}O_2 \text{ max}$ .

It is well known that aerobic training increases endurance performance. A well-trained individual could reasonably be expected to self-pace at a higher energy expenditure and to maintain this pace for a longer period of time than an untrained person. This investigation compared the speed and predicted energy expenditure (watts) of a group of trained and untrained (sedentary) males walking on four different terrains for an extended period of time, while carrying various external loads (4,6).

### Progress:

These findings were presented in detail in last year's annual progress report. During FY 82 these observations were published in the open literature (Ergonomics 25(5):393-400, 1982).

In summary, the data show that walking velocity and predicted energy expenditure were not different between the two groups ( $p > 0.05$ ), and did not decline with time as the subjects traversed the course for any of the load carriage conditions. Predicted relative energy expenditures, however, were significantly different ( $p < 0.01$ ) between the trained and the untrained subjects (mean for all conditions =  $35\% \dot{V}O_2$  max and  $44\% \dot{V}O_2$  max, respectively). Mean heart rate for the untrained group was also significantly greater than that of the trained group over each of the four terrains ( $p < 0.05$ ), and increased with increasing terrain difficulty. These data indicate that when men are required to do self-paced hard physical exercise of an extended duration, their walking velocity and energy expenditure will remain constant. Because the subjects were asked to refrain from running, and because the heaviest external load was 20 kg, fit individuals may have been limited by an inability to walk fast enough and/or to carry a heavy enough load to maintain the same relative energy expenditure as the unfit group. Consequently, the fit group could be expected to be capable of further extending the amount of physical exercise performed without a significant fall in energy expenditure.

### Presentation:

Levine, L., W.J. Evans, F.R. Winsmann and K.B. Pandolf. Prolonged self-paced hard physical exercise comparing trained and untrained men. Med. Sci. Sports Exercise 13(2):125, 1981.

### Publication:

Levine, L., W.J. Evans, F.R. Winsmann and K.B. Pandolf. Prolonged self-paced hard physical exercise comparing trained and untrained men. Ergonomics 25(5):393-400, 1982.

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6. Soule, R.G. and R.F. Goldman. Terrain coefficients for energy cost prediction. *J. Appl. Physiol.* 32:706-708, 1972.
7. Soule, R.G. and C.K. Levy. Voluntary march rate over natural terrain. *Fed. Proc.* 31:312, 1972.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Establishing Terrain Coefficients for Predicting the Energy  
Cost of Oversnow Movement Aided by Military Skis and  
Snowshoes

Investigators: Fred R. Winsmann, M.S., Gerald W. Newcomb, B.A. and  
William A. Lockwood, SFC, B.A.

Background:

Cold and snow are two factors that dominate the battlefield during winter. Cold can be an insidious enemy, injuring on contact and forcing the soldier to take active steps to insure his own survival. Snow can be an all-encompassing obstacle, forcing the soldier to learn the use of special techniques and equipment to move about the battlefield.

Oversnow movement during winter warfare often requires the use of skis and snowshoes (1,2,3). Skis and snowshoes are used to provide flotation toward the surface of the snow when snow is too deep for movement on foot. During cold weather operations in snow, skis are used when: speed is essential, long distances must be traveled, stealth is necessary, conditions allow; snowshoes are used when: moving through heavy brush, terrain is extremely rugged, speed is not essential, troops are not proficient on skis. When conditions permit, skis are chosen over snowshoes because they are faster and require less physical effort (work). However, it is much more difficult to master the techniques of skiing.

Preliminary work in FY 81 stressed the high energy cost requirement for novice cross-country skiers (i.e. infantry troops unfamiliar with skiing) and the necessity of learning and training in the skills and techniques required to work efficiently in this important aspect of oversnow movement. These findings were presented in detail in last year's annual progress report.

### Progress:

Unfortunately, insufficient snowfall in this area, as well as lack of manpower this past winter, prevented the continuation of this study in FY 82.

Plans are being made to continue this work on skiing and snowshoeing this winter (FY 83) with weather conditions and adequate snowfall permitting. We will attempt to add more information to our data base on fixed-pace skiing and snowshoeing at three different speeds (3.0 - 3.5 - 4.0 mph) with three different back loads (0 - 10 - 20 kg).

Future efforts will then concentrate on self-paced oversnow movement using boots, skis and snowshoes.

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1. Heinonen, A. O., M. J. Karvonen and R. Ruosteenoja. The energy expenditure of walking on snow at various depths. *Ergonomics* 2:289-393, 1959.
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3. Pandolf, K. B., F. R. Winsmann, M. F. Haisman, and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. *The Physiologist* 17:301, 1974.

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Hard Work for Walking on Snow of Various Depths

Investigators: Kent B. Pandolf, Ph.D., Fred R. Winsmann, M.S. and Ralph F. Goldman, Ph.D.

Background:

In a previous study, the metabolic energy expenditure and terrain coefficients for walking on snow were determined, using six male volunteer subjects. These subjects each walked for 15 minutes at each of two fix-paced speeds,  $0.67$  and  $1.12 \text{ m}\cdot\text{s}^{-1}$  (1.5 and 2.5 mph), on a treadmill (level) and on a variety of snow depths. Energy expenditure increased linearly with increasing depth of footprint depression, reaching a ratio of about 5:1 when a 45 cm footprint depression was compared to 0 cm depression. Although these subjects were considered above average in terms of physical fitness (mean  $\dot{V}\text{O}_2 \text{ max} = 51.4 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ ), all failed to complete the 15 minute walk because of exhaustion (at about 7.5 minutes) at an average footprint depth of 35.0 cm at a walking speed of  $1.12 \text{ m}\cdot\text{s}^{-1}$ . Practical limits for snow-walking without snowshoes not exceeding about 50%  $\dot{V}\text{O}_2 \text{ max}$  were developed, with 20 cm being the maximal depth at  $0.67 \text{ m}\cdot\text{s}^{-1}$  and 10 cm at  $1.12 \text{ m}\cdot\text{s}^{-1}$  (3).

Certainly, walking on snow is a very tiresome form of human locomotion (1-3). However, little is known about the self-paced work rates soldiers would adopt as "hard work" for prolonged snow-walking.

Progress:

Unfortunately, our Division was unable to conduct this study during the winter and early spring months of FY 82. Hopefully, in FY 83 it will be possible to go TDY to either Vermont or New Hampshire in order to conduct a field study to accomplish the research needs of this project. This option seems mandatory

considering the unpredictability of weather conditions and snow cover in this area.

Presentations:

1. Goldman, R. F., M. F. Haisman and K. B. Pandolf. Metabolic energy cost and terrain coefficients of walking on snow. Paper delivered at the Third International Symposium on Circumpolar Health, Yellowknife, Northwest Territory, (Canada) July 8-11, 1974.
2. Pandolf, K. B., F. R. Winsmann, M. F. Haisman, and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. *The Physiologist* 17:301, 1974.

Publication:

Pandolf, K. B., M. F. Haisman, and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. *Ergonomics* 19:683-690, 1976.

LITERATURE CITED

1. Heinonen, A. O., M. J. Karvonen and R. Ruosteenoja. The energy expenditure of walking on snow at various depths. *Ergonomics* 2:289-393, 1959.
2. Ramaswamy, S. F., G. L. Dua, V. K. Raizada, G. P. Dimri, K. R. Viswanathan, J. Madhaviah and T. N. Srivastava. Effect of looseness of snow on energy expenditure in marching on snow-covered ground. *J. Appl. Physiol.* 21:1747-1749, 1966.
3. Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. *Ergonomics* 19:683-690, 1976.

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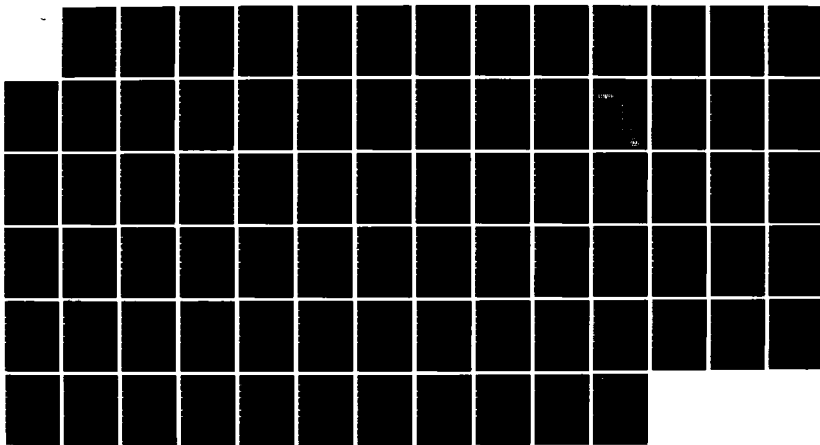
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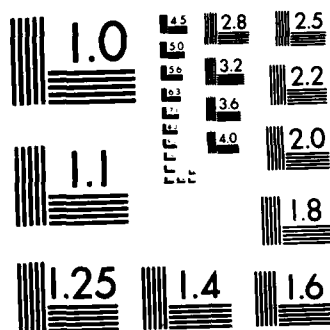
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Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military  
Performance as a Function of Environment, Clothing and  
Equipment

Study Title: Optimal Arm Crank Protocol for Determination of Peak  
Oxygen Uptake

Investigators: Michael N. Sawka, Ph.D., Kent B. Pandolf, Ph.D., Michael E.  
Foley, B.S. and Nancy A. Pimental, M.S.

Background:

Arm crank ergometry has traditionally been employed to enable determination of an individual's maximal aerobic power for upper body exercise. To our knowledge, research has not been reported examining the effects protocol selection has on maximal aerobic power values for upper body exercise. Protocol selection may be particularly important for upper body exercise where maximal aerobic power is probably limited by peripheral factors (i.e., local fatigue and muscle perfusion) rather than central circulatory factors. Maximal effort arm crank protocols have been reported that employed continuous as well as intermittent designs. It would seem that intermittent protocols (those which employ rest periods between exercise bouts) could minimize the effects of accumulated localized fatigue and thus elicit higher values for maximal aerobic power than continuous protocols. Maximal aerobic power values for upper body exercise could also be affected by crank rate, as a slower rate would necessitate development of a greater muscular tension to complete the same power output level. At high levels of muscular tension development, the intramuscular pressure can exceed perfusion pressure and thus decrease blood flow and limit aerobic metabolism. Maximal effort arm crank protocols have been reported that employed crank rates of 30 through 70 rpm.

The purpose of the present investigation was to evaluate four maximal effort arm crank protocols for their effectiveness in eliciting maximal aerobic power (peak  $\dot{V}O_2$ ). Comparisons were made between: (1) a continuous (CON) and an intermittent (INT) protocol (both employing 50 rpm), and (2) the continuous protocol employing crank rates of either 30, 50 or 70 rpm.

### Progress:

Thirteen healthy male volunteers participated in the present series of experiments. These subjects had a mean ( $\pm$  SE) age of  $24 \pm 1$  yr and weight of  $78.0 \pm 2$  kg. Before any experimental testing, each subject completed several practice sessions on the arm crank ergometer. The subjects were then randomly assigned a continuous or intermittent maximal effort protocol (at 50 rpm) to be completed on a future date. The alternate protocol was then performed within a 3-day to 2-week period. Approximately one month after completing these tests, the subjects were asked to complete a second series of experiments. These experiments encompassed completing the continuous maximal effort protocol using crank rates of either 30, 50 or 70 rpm. These three tests were completed in a random order. In addition, each test was spaced by at least two days of rest and completed within a two-week period. All tests were conducted in a comfortable environment ( $T_a = 20^\circ\text{C}$ ; rh = 30%).

The progressive intensity but intermittent protocol employed exercise bouts that were three minutes in duration and interspersed by 15-minute rest periods. The initial power output (PO) level corresponded to 70% of each subject's predicted age adjusted maximal heart rate ( $220 \text{ b} \cdot \text{min}^{-1}$  minus age). Each subsequent PO level was  $\sim 25\text{W}$  greater than the preceding PO level. The progressive intensity but continuous protocol also employed three-minute exercise bouts. However, the initial PO was 75W, and it was increased by  $\sim 25\text{W}$  every three minutes. Physiological data were obtained during the 2nd and 3rd minutes of each exercise period. Each exercise test was terminated by physical exhaustion.

This investigation resulted in a total of 49 maximal effort arm crank tests being administered. Eleven subjects were tested during the first group, and nine subjects were tested during the second group of experiments. Since seven subjects completed both groups of experiments, we were able to examine test-retest peak  $\dot{V}\text{O}_2$  data for the continuous protocol at 50 rpm. A mean ( $\pm$  SE) peak  $\dot{V}\text{O}_2$  of  $2.55 \pm 0.15$  and  $2.65 \pm 0.15 \text{ l} \cdot \text{min}^{-1}$  was found for test #1 and #2, respectively. These values were not significantly different, and generated a nonsignificant ( $p > 0.05$ ) correlation coefficient of  $r = 0.63$ . A plateauing of oxygen uptake ( $< 60 \text{ ml}$  increase) between exercise bouts was demonstrated by 6 and 3 subjects for the INT-50 and CON-50 protocols, respectively. The  $\text{PO}_{\text{max}}$ , which was defined as the highest PO attained during the test, was found to be significantly lower for the CON-50 than INT-50 protocol. No significant

differences were found between the CON-50 and INT-50 protocol for peak  $\dot{V}O_2$ , maximal pulmonary ventilation ( $\dot{V}E$  max), maximal heart rate (HR max), or maximal blood lactate concentration (LAmax) responses. A significant ( $p < 0.01$ ) correlation coefficient of  $r = 0.87$  was found between peak  $\dot{V}O_2$  responses for the CON-50 and INT-50 protocols.

During the second group of experiments a plateauing of oxygen uptake was not demonstrated by our subjects for the CON-30 protocol. However, a plateauing of oxygen uptake was observed by 2 and 3 subjects for the CON-50 and CON-70 protocols, respectively. Table 1 presents the POmax and physiological responses obtained when employing the CON design at crank rates of either 30, 50 or 70 rpm. For this group of experiments, the repeated measures analysis of variance generated a significant F value for each of the studied variables. These significant values enabled the CON-50 to be compared to the CON-30 and CON-70 protocols. In comparison to the CON-50, significantly higher peak  $\dot{V}O_2$  and  $\dot{V}E$  max responses were elicited by the CON-70, whereas significantly lower POmax, peak  $\dot{V}O_2$ ,  $\dot{V}E$ max, HRmax, and LAmax values were elicited by the CON-30.

Our data indicate that an intermittent design, which theoretically might minimize the effects of accumulated muscular fatigue, has no advantage for maximal effort arm crank testing. However, we found that the use of higher crank rates, which might improve muscle perfusion, improves elicited peak  $\dot{V}O_2$  values.

TABLE 1

Maximal power output and physiological responses to continuous maximal effort arm crank protocols at various crank rates (n = 9)

	POMax	Peak $\dot{V}O_2$	$\dot{V}E_{max}$	HRmax	LAmx
	W	$l \cdot \min^{-1}$	$l \cdot \min^{-1}$	$b \cdot \min^{-1}$	$mmol \cdot l^{-1}$
<u>Control protocol</u>					
50 rpm					
Mean	169	2.62	124.3	182	11.7
SE	7	0.11	6.5	3	0.7
<u>Experimental protocols</u>					
30 rpm					
Mean	122	2.33	95.3	167	8.3
SE	3	0.09	5.9	3	0.7
P	< 0.01	< 0.05	< 0.05	< 0.01	< 0.05
% $\Delta$	-28	-11	-23	-8	-29
70 rpm					
Mean	179	2.89	142.2	186	11.7
SE	7	0.13	5.5	2	0.9
P	NS	< 0.05	< 0.05	NS	NS
% $\Delta$	+6	+10	+14	+2	0

P, probability level; NS, not significantly different; %  $\Delta$ , percent difference that experimental values are from control values; POMax, maximal power output; Peak  $\dot{V}O_2$ , peak oxygen uptake;  $\dot{V}E_{max}$ , maximal pulmonary ventilation; HRmax, maximal heart rate; LAmx, maximal blood lactate concentration.

#### Presentations:

1. Sawka, M.N., M.E. Foley, N.A. Pimental, M.M. Toner and K.B. Pandolf. Arm crank protocols for determination of maximal aerobic power. Med. Sci. Sports Exer. 14:168-169, 1982.
2. Foley, M.E., M.N. Sawka, N.A. Pimental and K.B. Pandolf. Physiological determinants of upper body peak oxygen uptake. Fed. Proc. 41:1592, 1982.

#### Publication:

Sawka, M.N., M.E. Foley, N.A. Pimental and K.B. Pandolf. Determination of maximal aerobic power during upper body exercise. J. Appl. Physiol. (In press).

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier Effectiveness

Work Unit: 127 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Body Temperature Responses to Upper Body Exercise in a Neutral Thermal Environment

Investigators: Nancy A. Pimental, M.S., Michael N. Sawka, Ph.D. and Kent B. Pandolf, Ph.D.

Background:

Few investigations have attempted to examine thermoregulatory mechanisms and temperature responses for upper body exercise (1,4,9,10). These investigations have generally concluded that the magnitude of thermal responses for upper body exercise may be the same (4, 9) or lower (1) than those responses for lower body exercise. However, careful examination of those investigations indicate that a limited number of observations, technical problems, and inconsistent results make any conclusion tenuous. Direct comparisons between thermal responses for upper body and lower body exercise were conducted on only 6 individuals. The use of rectal measurements ( $T_{re}$ ) may have spuriously elevated temperature values for lower body exercise and biased subsequent conclusions (10). Also, it is of question if all of the presented  $T_{re}$  values represented equilibrium values (1). In addition, some of the investigations present data which appears to be inconsistent with their conclusions (4,9).

A number of potential mechanisms could cause a greater heat gain during upper body than lower body exercise. For example, arm crank exercise has been shown to be metabolically less efficient than cycle exercise (2). This relative inefficiency indicates that, for a given  $\dot{V}O_2$  level, more heat will be released (16) and need to be dissipated. Davies et al. (5) have reported that during exercise at a given  $\dot{V}O_2$  level changes in plasma catecholamine concentrations were inversely related to the skeletal muscle mass employed. These data indicate that catecholamine output is greater for upper body than lower body exercise. Therefore, for a given absolute intensity, arm crank exercise should elicit a

higher level of arterial cutaneous vasoconstriction which inhibits peripheral blood flow and heat dissipation. In addition, during upper body exercise a pooling of venous blood could occur in the legs due to decreased skeletal muscle pump activity. This pooling might become accentuated in a hot environment from increased venous compliance (14) and cause a displacement of central blood volume to the periphery (7). This peripheral displacement could result in a decreased mean arterial pressure (6), ventricular filling pressure (12), and cardiac output (11) during exercise. This would cause decreased cutaneous blood flow which would elevate body temperature, and/or elicit a decreased muscle perfusion which would limit exercise performance.

Likewise, potential mechanisms could also be proposed that would result in a greater heat loss for upper body exercise. Wells and Buskirk (15) as well as Cooper et al. (3) have suggested that a significant fraction of heat released from contracting muscles may be transferred by vertical vascular convection to the overlying skin. In support of this, Wade and Veghte (13) have provided thermographic data indicating that considerable heat loss does indeed occur from contracting muscles to overlying skin during exercise. The magnitude of this heat loss should be directly proportional to the surface area of overlying skin to muscle mass ( $A_D:M$ ) ratio (8), and be inversely proportional to thickness of subcutaneous adipose tissue (13). It seems reasonable to expect that in comparison to the legs, the arms would have a higher  $A_D:M$  ratio. In addition, a smaller skinfold thickness over the bicep and tricep areas than over the front and back thigh areas has been reported (17). As a result of these possible morphological advantages, metabolic heat may be more easily dissipated during upper body than lower body exercise.

#### Progress:

Nine male volunteers, with a cycle ergometer peak  $\dot{V}O_2$  ( $\bar{X} \pm SD$ ) of  $49 \pm 7 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$  and arm crank ergometer peak  $\dot{V}O_2$  of  $35 \pm 6 \text{ ml} \cdot \text{kg} \cdot \text{min}^{-1}$  completed four prolonged exercise tests within a 3-week period. Subjects performed arm crank and cycle exercise at the same absolute  $\dot{V}O_2$  ( $1.60 \text{ l} \cdot \text{min}^{-1}$ ) and at the same percent of ergometer-specific peak  $\dot{V}O_2$  (60%). During each 60-min exercise bout, blood pressure was measured every 10 min, heart rate every 5 min, oxygen uptake every 20 min, ratings of perceived exertion every 10 min, and venous blood samples every 20 min. Rectal, esophageal, and skin temperatures were recorded every 2 min. Currently, the data is being statistically analyzed.

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FOR REVIEW

(128)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD DR&F-AK 6-64	
3. DATE PREV. SUMRY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8. DISB'TN INSTR'H	9. SPECIFIC DATA CONTRACTOR ACCESS	9. LEVEL OF SUM A. WORK UNIT
82 04 30	D.CHANGE	U	U	DA OC 6121	82 09 30	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
10. NO./CODES*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER			
a. PRIMARY	62777A	3E162777A879	BE	128			
b. CONTRIBUTING							
c. CONTINUING	STOG 80-7.2-4						
11. TITLE (Precede with Security Classification Code)							
(U)Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS*							
013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology; 007900 Occupational Medicine; 002300 Biochemistry							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
76 10		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	
a. DATES/EFFECTIVE:				PRECEDING		b. FUNDS (in thousands)	
b. NUMBER:				82		8.0	
c. TYPE				FISCAL YEAR		177	
d. KIND OF AWARD:				CURRENT		8.0	
e. CUM. AMT.				83		154	
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME:*				NAME:*			
USA RSCH INST OF ENV MED				USA RSCH INST OF ENV MED			
ADDRESS:*				ADDRESS:*			
NATICK, MA 01760				NATICK, MA 01760			
RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: BANDERET, LOUIS E., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4858			
21. GENERAL USE				SOCIAL SECURITY ACCOUNT NUMBER:			
Foreign Intelligence Not Considered				ASSOCIATE INVESTIGATORS			
				NAME: KOBRICK, JOHN L., Ph.D.			
				NAME: FINE, BERNARD J., Ph.D. POC:DA			
22. KEYWORDS (Precede each with Security Classification Code)							
(U)Human Volunteer; (U)Team Performance; (U)Environmental Stress; (U)Sustained or Continuous Operations; (U)Fatigue, Mental; (U)Psychomotor & Cognitive Functions; (U)Motivation.							
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code)							
<p>23. (U) Level of training, task organization and small unit "cohesion" are significant determinants of performance and of biological reaction in scenarios where units must fight for sustained periods or in adverse climates or microenvironments. This work unit quantifies, correlates and describes in actual military contexts the interaction of: 1) harsh environmental conditions; 2) common military stressors such as mission demands, noise, crowded work space, and sustained operations with disrupted sleep; 3) the acute physiological, biochemical, symptomatic and psychosocial status of team members; 4) individual and team operational effectiveness over time.</p> <p>24. (U) Fire Direction Center (FDC) teams from Artillery units were tested for extended periods in naturalistic combat simulations of that "model" command/control and communications system. Multidisciplinary data are analyzed to assess operational as well as biological cost to teams functioning under complex stress, determine rates of recovery following exposure, identify predictors of operational degradation, and establish mechanisms of action. Collaboration in training exercises and Operational and FDTE field tests of other DA agencies is extending the methodology to other Army teams and perfecting experimental "models" to test prophylactic or therapeutic interventions.</p> <p>25. (U) 81 10 - 82 09 Data analysis of artillery FDC performance continued, but made limited progress due to commitments to develop other work unit areas. Data collection was completed in a study of individual factors related to attrition of students in the MOS 05H (Morse Code Interceptor) course at USAISD (Ft. Devens, MA). Data analysis is underway.</p>							

\*Available to contractors upon originator's approval

DD FORM 1498  
1 MAR 66PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65  
AND 1498-1 1 MAR 66 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS  
Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness  
Work Unit: 128 Army Team Health and Efficiency Under Environmental  
and Situational Stress in Simulated Combat Operations  
Study Title: An Exploratory Investigation of Demographic and  
Psychological Factors Related to Sustained Military  
Operations: Morse Code Interceptor Training - MOS 05H\*  
Investigator: Bernard J. Fine, Ph.D.

Background:

The US Army Intelligence School, Fort Devens, MA (USAISD) trains enlisted personnel to be Morse Code Interceptors (MOS 05H). The 23-week course is extremely demanding. In addition to daily 6-hour training sessions in which trainees monitor incoming Morse Code signals and transcribe them into alphanumeric form on special typewriters, considerable time is spent on homework, practice, make-up work and other course work. Students have one hour of free time from 0400 until lights-out at 2100 daily, five days a week. The training process begins with the learning of typing skills and Morse Code and is continued through a self-paced, computer-controlled process, until specific criteria of performance are achieved and maintained. High levels of proficiency, both with regard to speed and accuracy are required.

The work is repetitive, tedious and mentally fatiguing for most individuals, since it requires constant alertness and quickness of response. Since the training is largely self-paced, along with some interaction with instructors, the duration of the course varies from person to person. Some individuals require considerably longer than others to complete the training; others drop out along the way.

The attrition rate is very high, reaching 40% in some years, but the causes have not been identified. Current tests used to screen students at induction are only partially adequate for predicting success or failure, so that considerable amounts of time and money are spent in security checks and in training of students who eventually prove to be unsuitable.

After graduation, many 05H personnel are assigned to fixed facilities where, in the event of war, they may have to take defensive measures against CB warfare threats, measures which themselves impose thermal and other stresses which can interfere with performance. Other 05H personnel are assigned to mobile field units where they also may work in uncomfortable or hazardous climates or can be constrained by protective devices and/or systems which interfere with the performance of their duties. It is essential to national security that these key personnel be able to maintain accurate, thorough radio monitoring performance under such adverse conditions.

The research described here is a pilot study designed to develop a system for predicting successful performance in sustained military operations. The 05H course lends itself readily to this purpose. A long-term goal is to study trained 05H personnel under controlled conditions of environmental stress and sustained operations, with and without CB protective gear, to determine the effects of that stress on performance.

Data collection started October 80 and ended in February 82. All incoming students assigned to the 05H course were briefed during their indoctrination week and were asked to volunteer for the study. Approximately 430 students volunteered. Volunteer rate was about 95%.

A battery of tests, inventories, and questionnaires was administered to the volunteers recruited each week. Groups ranged in size from two to over 20. The battery included questionnaires dealing with family background and other demographic information, a survey of attitudes and interests on a number of general issues, personality and cognitive tests and a sampling of simple performance measures.

Unlike typical selection batteries which either focus on the specific skills involved in a particular job or on broad dimensions such as personality, the approach here is designed to obtain a sampling of a wide variety of traits and abilities deemed to be related to various aspects of the job and the milieu in which it takes place.

#### Progress:

Data analysis is continuing. We have performed a complex discriminant function analysis on the data of the first 200 students tested, all of whom have either graduated or dropped out of school. Since the discriminant function

requires complete data, we had to eliminate 47 Ss who did not answer certain of the questions asked of them. For the 153 remaining Ss, the actual attrition rate was approximately 39%. The discriminant function analysis indicated that a battery composed of 33 of our predictor items could have predicted 93% of those who dropped out. In other words, by a sort of statistical hindsight, we estimate that had our battery been used to select student candidates for the school, the attrition rate could have been dropped to below 5% while losing only 11% of potential graduates. This is an extremely effective result, and we are regarding it with much caution.

The next step in the data analysis will be to apply the same predictive equations to the second half of the student population to see if the equations will predict equally well to that group. If they do, then the effectiveness of multi-dimensional prediction battery will have been substantiated and we will have the nucleus of an effective screening battery. This will then require further validation and evaluation using additional students in the 05H course.

Data analysis came to a complete standstill in August because of the termination of employment of our computer programmer. A term employee, she could not be extended and, in the absence of any authorized positions against which to hire her, she was forced to leave. Although before leaving she spent considerable time documenting the complex computer techniques she had used, it was not possible without her actual presence to get the system running. After considerable effort, we have secured her services as a part-time employee, on an intermittent basis, to continue to lend her expertise to the project.

\*Note: Title has been changed from FY82. We had taken measures of classroom temperatures, intending to relate them to student performance. However, because of considerable shifting of students (recycling), it is impossible to know which students were in which classroom at what time. Hence, "environmental" has been dropped from the title.

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL DD FORM 1498A	
3. DATE PREV SUMMARY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8. DISB'N INSTR'N	9. SPECIFIC DATA CONTRACTOR ACCESS	10. LEVEL OF SUM A. WORK UNIT
81 10 01	H. TERMINATED	U	U	NA	NL	<input checked="" type="checkbox"/> YES <input type="checkbox"/> NO	
10. NO. CODES*	PROGRAM ELEMENT	PRC SCT NUMBER	TASK AREA NUMBER		WORK UNIT NUMBER		
A. PRIMARY	62777A	3E162777A879	BF		129		
B. CONTRIBUTING							
C. CONTRIBUTING	STOG 80-7.2:4						
11. TITLE (Precede with Security Classification Code)*							
(U) Medical Aspects of Physical Fitness Training (22)							
12. SCIENTIFIC AND TECHNOLOGICAL AREAS*							
012500 Personnel Training & Evaluation; 016200 Stress Physiology; 003500 Clinical Med							
13. START DATE		14. ESTIMATED COMPLETION DATE		15. FUNDING AGENCY		16. PERFORMANCE METHOD	
81 07		CONT		DA		C. IN-HOUSE	
17. CONTRACT/GRANT				18. RESOURCES ESTIMATE		19. PROFESSIONAL MAN YRS	
A. DATES/EFFECTIVE:				PRECEDING		B. FUNDS (In thousands)	
B. NUMBER:*				FISCAL YEAR		C. CURRENT	
C. TYPE:				82		0	
D. AMOUNT:				0		0	
E. KIND OF AWARD:				0		0	
F. CUM. AMT.							
19. RESPONSIBLE DOD ORGANIZATION				20. PERFORMING ORGANIZATION			
NAME:*				NAME:*			
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RESPONSIBLE INDIVIDUAL				PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)			
NAME: IRONS, ERNEST M. JR., COL, MSC				NAME: VOGEL, JAMES A., Ph.D.			
TELEPHONE: 256-4811				TELEPHONE: 256-4800			
21. GENERAL USE				22. KEYWORDS (Precede EACH with Security Classification Code)			
Foreign Intelligence Not Considered				(U) Physical Fitness; (U) Physical Training; (U) Fitness Evaluation;			
				(U) Aerobic Fitness; (U) Coronary Heart Disease; (U) Coronary Risk Index; (U) Human Volunteer.			
23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)							
<p>23. (U) An adequate level of physical fitness in military personnel is necessary to achieve optimal health and physical work capacity and thereby maintain military readiness. This requirement for readiness exists at all levels of age, rank and assignment. Thus, physical fitness training and fitness evaluation is necessary throughout a military career. Due to the fact that the risk for and the incidence of heart disease and other medical conditions increases with age, it is important to detect underlying medical problems in personnel before physical training and testing are carried out. The objective of this program is to develop improved means of detecting disease and insure that training and evaluation are safe and cost effective at all age levels.</p> <p>24. (U) This unit will include studies to: (a) identify factors which place individuals at risk for untoward cardiovascular accidents, heat injuries, orthopedic injuries; (b) quantify the effectiveness and cost-benefit relationships of training mode, intensity and life style modification to desired fitness goals; and (c) develop educational and motivational strategies to improve participation in Army physical fitness programs.</p> <p>25. (U) 81 08 - 82 09 To identify coronary artery disease (CAD) in asymptomatic active duty personnel over the age of 40, a cardiovascular risk factor screen was performed in 249 males at Carlisle Barracks, PA. The efficacy of this screening procedure was evaluated against an exercise tolerance test (ETT), Cardiokymography (CKG) and coronary angiography. Elevated plasma lipids (cholesterol and triglycerides) and a high risk index based upon the Framingham risk equations best predicted CAD in individuals with an abnormal ETT and/or CKG. This work unit is terminated and further studies will be reported under WU 125.</p>							

\*Available to contractors upon originator's approval

Program Element: 6.27.77.A MEDICAL FACTORS LIMITING SOLDIER  
EFFECTIVENESS

Project: 3E162777A879 Medical Factors Limiting Soldier  
Effectiveness

Work Unit: 129 Medical Aspects of Physical Fitness Training

Study Title: Cardiovascular Screening Evaluation to Test for Coronary  
Artery Disease in Asymptomatic males over the age of 40

Investigators: John F. Patton, Ph.D., James A. Vogel, Ph.D., William L.  
Daniels, MAJ, MSC, Ph.D., Jerel Zolnick, MAJ, MC, James  
Davia, COL, MC, WRAMC and Julius Bedynek, COL, MC,  
OTSG

Background:

The Chief of Staff, US Army, initiated a new physical training program for all US Army personnel as of 15 Oct 1980 (Interim Change 101, AR 600-9, 15 Oct 80). This program emphasizes aerobic physical fitness for all age groups (17-60) on active duty. Since potential health risks of both physical training and testing are greater in personnel over the age of forty, a mandatory medical and cardiac screen is indicated, in order to try to predict and prevent untoward cardiovascular events. During the period Sep 80 - May 81, a pilot study was conducted at Ft. Benning, GA to attempt to identify latent coronary artery disease (CAD) in 295 asymptomatic military personnel by the use of multiple serial screening procedures (USARIEM Annual Progress Report, pp. 517-524, 1981).

The objective of the present study was to extend the multistage cardiovascular screening evaluations to another group of Army personnel over the age of forty to further test the validity, accuracy and efficacy of such procedures in predicting cardiovascular events in asymptomatic personnel.

Progress:

The study was conducted at the US Army War College (AWC), Carlisle Barracks, PA. An initial primary risk factor screen was applied to 249 active duty personnel (faculty, staff and students) over the age of 40 at the AWC. This included a risk factor analysis as developed by the Framingham Heart Study (1), a resting ECG, and a directed cardiovascular physical and history to detect

abnormal signs and symptoms. All individuals then underwent a secondary screen which included a symptom-limited graded exercise test (GXT) and cardiokymography (CKG). At the time of the GXT, maximal oxygen uptake ( $\dot{V}O_2$  max) was determined using the Douglas bag technique. Those individuals who had an abnormal GXT and/or an abnormal CKG were referred for further medical screening to include a stress thallium and/or coronary angiography to determine the presence of CAD.

To characterize the sample studied, Table 1 presents the mean data for the anthropometric, physiologic and risk factor measures made:

TABLE 1

	<u>MEAN + SD</u>	<u>RANGE</u>
AGE (Yrs)	43.7 $\pm$ 3.2	39 - 55
Ht (Cm)	180.0 $\pm$ 6.9	150 - 201
Wt (Cm)	83.4 $\pm$ 9.8	60 - 118
% Body Fat	24.0 $\pm$ 4.2	12.7 - 34.3
$\dot{V}O_2$ max (ml/kg • min)	40.8 $\pm$ 6.1	26.7 - 58.0
HR max	179 $\pm$ 10	142 - 204
TM Time	15.1 $\pm$ 2.1	10.3 - 21.0
Systolic BP	127 $\pm$ 14	98 - 170
Diastolic BP	82 $\pm$ 9	50 - 110
Cholesterol	230 $\pm$ 43	130 - 380
HDL	54 $\pm$ 14	15 - 99
Chol/HDL	4.5 $\pm$ 1.6	2 - 17
Triglycerides	106 $\pm$ 76	24 - 732
FBS	98 $\pm$ 16	61 - 300
Risk Index (%)	3.5 $\pm$ 2.9	0.3 - 20.7

Analysis of the data regarding the efficacy of the screening process used to predict the likelihood of CAD prior to engaging in physical training testing has not been completed. However, the secondary screen of a GXT and CKG resulted in 33 (13%) abnormal responses who had coronary angiography for the following indications: 16 with a positive GXT defined as >1 mm ST depression; 6 with a concordant positive GXT and CKG; 4 with ventricular tachycardia during a normal GXT, 5 with only an abnormal CKG; 2 with myocardial infarction within

60 days post study despite normal results. The findings of coronary risk variables compared between those individuals with CAD (> 50% luminal narrowing) and those with normal coronaries, based on coronary angiography, were as follows:

	Normal (n = 20)			CAD (n = 13)			P
Chol	229	±	39	286	±	45	< .001
Chol/HDL	4.4	±	0.9	6.0	±	1.3	< .001
TRIG	96	±	50	147	±	54	< .01
Risk Index	3.8	±	3.7	7.8	±	5.4	< .05

Other risk factors measured were not significantly different between the two groups. The data suggest, therefore, that plasma lipid levels (cholesterol, HDL and triglycerides) best predict CAD in asymptomatic males with an abnormal GXT and/or CKG.

#### Presentation:

Zoltick, J., J. Patton, J. Vogel, W. Daniels, J. Bedynek and J. Davia. Cardiovascular screening evaluation to test for coronary artery disease in asymptomatic males over the age of 40. American College of Cardiology, March 1983.

#### LITERATURE CITED

1. Kannel, W. B., D. McGee, and T. Gordon. A general cardiovascular risk profile: The Framingham Study, Amer. J. Cardiol. 38: -51, 1975.

## Animal Care and Animal Modeling

### Background:

Over the years, the position of Chief, Animal Care Facility has expanded to include several areas of responsibility. These responsibilities include:

- 1) surgical development of new and unique animal models to support the research mission of the US Army Research Institute of Environmental Medicine (USARIEM), and to serve as a source of expert veterinary medical advice to the investigators utilizing research animals,
- 2) performance of both chronic and acute aseptic surgical techniques and procedures to produce statistically significant numbers of healthy animal models,
- 3) administrative management of the Animal Care Facility to include the physical plant and animal care personnel in accordance with standards of the American Association for the Accreditation of Laboratory Animal Care (AAALAC),
- 4) maintenance of the health of the laboratory animal population through a sound conditioning program, a preventative medical program for all animals and the observation, diagnosis and treatment of medical and surgical problems occurring in the laboratory animal population, and
- 5) chairing of USARIEM's Animal Use Committee to review and make recommendations to the Commander for his approval or disapproval of proposed research protocols utilizing laboratory animals.

### Progress:

#### 1. Veterinary Support:

Aside from the routine daily animal care activities, the Altitude Research Division required surgical procedures to be performed on caprine models in support of several protocols. Two protocols by Dr. Weinberger, "Effect of Altitude on Plasma and Cerebrospinal Fluid Endorphin Levels in Goats" and "Effect of Synthetic Neuropeptides on Ventilatory Control in Goats," required the performance of eleven permanent carotid loops and cisterna magna cannulations for sampling of arterial blood and cerebrospinal fluid, respectively. In addition, Swan-Ganz catheterization was performed acutely on an "on-call"

basis. These same caprine models were used in several other protocols requiring carotid loops.

Six goats were conditioned, medically screened, and maintained as blood donors in support of the protocol "Evaluation of the Capacity of Therapeutic Agents to Ameliorate Heat-Induced Liver Damage in the Isolated Perfused Liver" by Dr. W. D. Bowers. A high level of nutrition, zoonotic surveillance, frequent hemograms and 21 parameter biochemical profile evaluations were employed to assure the health of these animals as well as the safety of the personnel handling the collected blood.

Twenty canines were utilized in the Cold Research Division protocol "The Development and Characteristics of Models of Cold Injury and Hypothermia" by Dr. Donald Roberts. All twenty of these dogs were chronically splenectomized. Following this procedure, a Konigsberg pressure transducer was implanted in the left ventricle of the heart by a left thoractomy technique. In addition, ten dogs received an aortic flow probe installed concurrently with the Konigsberg pressure transducer. A healthy, instrumentated model was presented to Dr. Roberts approximately two weeks post-procedure for hypothermia studies.

Six porcines were used to supply the necessary tissue requirements in support of the Cold Research Division protocol "Effects of Cold Stress on Endothelial Cell-Induced Platelet Aggregation" by Dr. Stephen Bruttig. Since various tissues from the body, including aorta and brain, were to be collected not only aseptically but also in a viable status, the problem of collection techniques and anesthesia were considered carefully. To date, this problem has been solved by utilizing a standard surgical thoracotomy and craniotomy approach under neuroleptanalgesia supplemented with  $O_2$  -  $N_2O$  - Halothane anesthesia when needed.

Surgical procedures, their numbers, the species involved, and the nature of their use (acute vs. chronic) performed in support of USARIEM protocols in FY82 are listed in Table 1.

TABLE I  
Surgical Procedures Performed to Support Research During FY 82

Surgical Procedures	Species	Number of Procedures	
		Chronic	Acute
Konigsberg Thoracotomy	Canine	20	
Aortic Flow Probe	Canine	10	
Implantation			
Splenectomy	Canine	20	
Carotid Loop	Caprine	14	
Cisterna Magna Cannulization	Caprine	10	
Thoractomy/Craniotomy	Porcine		6
Swanz-Ganz Catheterization	Caprine		Numerous

## 2. Animal Use Committee:

The Animal Use Committee, continuing in its responsibility to: 1) oversee the use of laboratory animals and to insure that the information sought by the use of laboratory animals is sufficiently important to warrant their use, 2) insure that the maximum amount of information consistent with good scientific research practices is obtained, 3) use the minimum number of animals necessary for scientific validity, 4) after adequate consideration of the experimental design, laboratory limitations and alternative species, select the species most suitable, and 5) insure that the description of the procedures is reasonably complete and minimizes pain and discomfort to the greatest extent possible without compromising the objectives; reviewed the following protocols:

1. "Evaluation of the Isolated Perfused Liver as a Model for Titrating Chemical Toxicity" - Dr. Wilbert D. Bowers
2. "Non-Invasive Measurement of Blood Gases during Hypothermia" - Dr. Donald Roberts
3. "Work in the Heat: Effects of Sub-Chronic Agent Antidote Exposure"- Dr. Ralph Francesconi
4. "Dietary Induced Hyponatremia: Effects on the Ability to Work in the Heat" - Dr. Ralph Francesconi

5. "Treatment of Frostbite by Dimethyl Sulfoxide" - CPT John Gadarowski
6. "Role of Carotid Baroreceptors in Influencing Cold-Induced Vasodilation" - CPT Carl Ohata
7. "Measurement of Endorphin Levels in Plasma and Cerebrospinal Fluid in Goats" - Dr. Steven Weinberger
8. "The Role and Mechanism of Fasting and Feeding in Mouse Tolerance to Extreme Hypoxia" - Dr. T. Scott Johnson
9. Addendum to the approved protocol "Development of a Plethysmograph for Measuring Pulmonary Ventilation in Unrestrained Rodents" - Dr. Steven Weinberger
10. "Effects of Cold Stress on Endothelial Cell-Induced Platelet Aggregation" - CPT Stephen Bruttig
11. "Sympathetic Dopaminergic Mediation of Cold-Induced Vasodilation" - CPT Carl Ohata
12. Addendum to the approved research protocol "Atropinization and the Predisposition to Performance Decrements and to Fatal Heatstroke" - Dr. Roger Hubbard
13. Addendum to the approved research protocol "The Mouse as an Animal Model to Test Pharmacologic Agents in Hypobaric Hypoxia" - CPT Paul Rock
14. "Effects on Profound Hypothermia and Rewarming on Isolated Perfused Liver" - Dr. Wilbert Bowers
15. "Effect of Synthetic Neuropeptides on Ventilatory Control in Goats" - Dr. Steven Weinberger
16. "Effect of Altitude on Plasma and Cerebrospinal Fluid Endorphin Levels in Goats" - Dr. Steven Weinberger

### 3. Animal Care

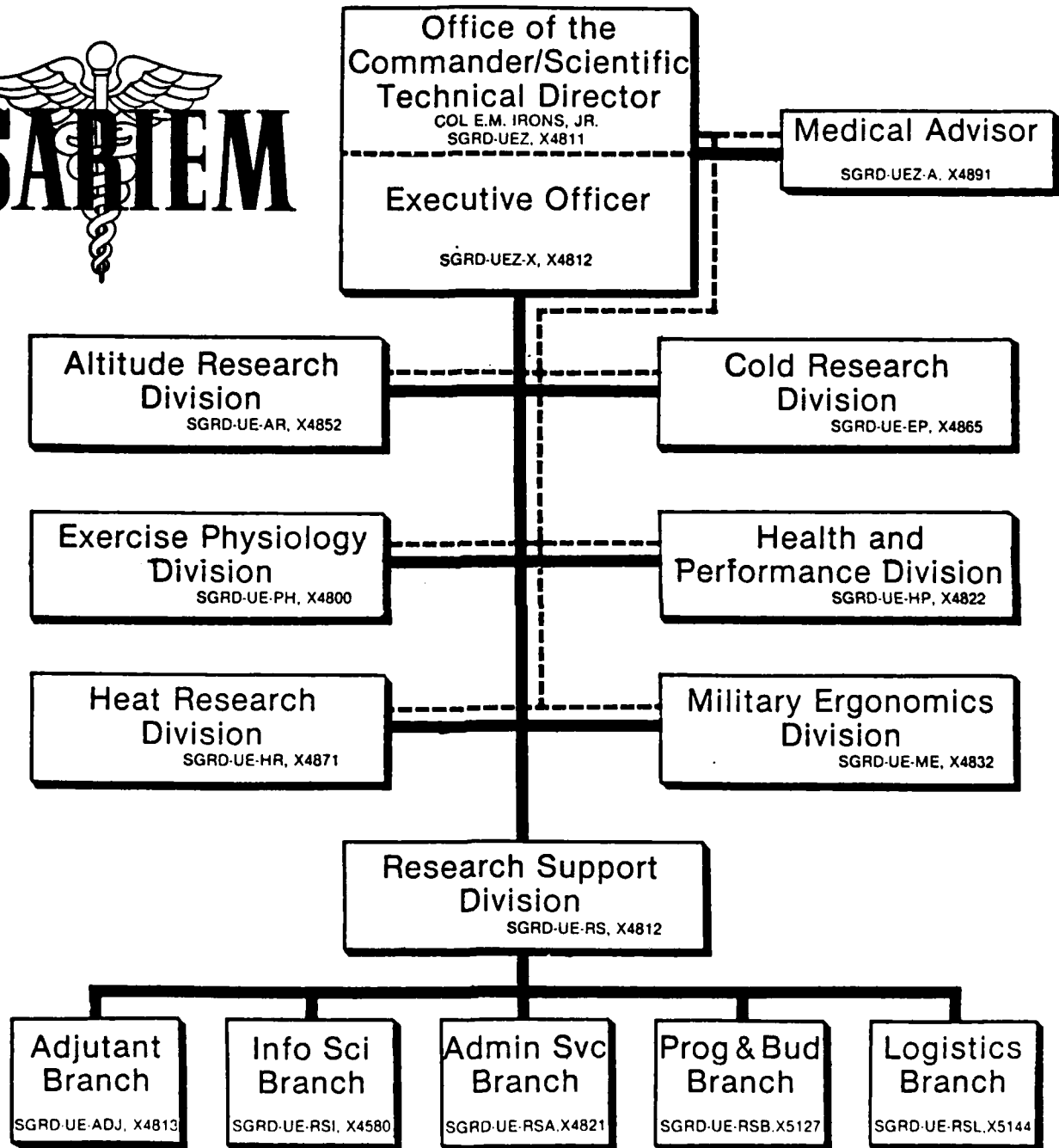
The Animal Care Facility, in accordance with regulations governing its accreditation with the American Association for Accreditation of Laboratory Animal Care (AAALAC), was required in FY82 to undergo an on-site inspection (required every three years) by an official AAALAC inspection team for reaccreditation. This inspection took place 16 August 1982. The Animal Care Facility was found fully acceptable for full AAALAC accreditation for another three years.

To further facilitate the operation of the Animal Care Facility, a new comprehensive SOP was introduced as well as a new animal identification system. A preventive medicine and conditioning program for each animal species consisting of vaccination, medical monitoring, quarantine and isolation, and surveillance helps maintain and guarantee the health of the research laboratory animals. An extensive vermin and insect extermination program have been used continuously. In FY 82 no serious disease outbreaks occurred in the animal population.

TABLE 2  
Animals Cared for During FY 82

Species	Average Daily	Annual Total
Rats	220	2066
Mice	100	1000
Rabbits	14	120
Cats	5	74
Dogs	12	20
Goats	16	42
Pigs	1	6

# US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE NATICK, MASSACHUSETTS 01760



APPROVAL: Ernest M. Irons Jr.  
ERNEST M. IRONS JR.  
COL, MSC  
Commanding

DATE: 27 September 1982



COMMAND   
TECHNICAL   
COORDINATION

APPENDIX B  
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APPENDIX C  
ABSTRACTS AND PRESENTATIONS

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APPENDIX D  
CONSULTATIONS

Legend

ALTITUDE RESEARCH DIVISION	AR
COLD RESEARCH DIVISION	CR
EXERCISE PHYSIOLOGY DIVISION	PH
HEALTH & PERFORMANCE DIVISION	HP
HEAT RESEARCH DIVISION	HR
MILITARY ERGONOMICS DIVISION	ME

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Ms Debra Alan Family Safety Magazine Chicago, IL	Dressing warm for winter	ME	October
Mr. Richard Armstrong USAHEL:USAAVNC FT Rucker, AL	Review and discussion of draft of heat/cold stress for Army Aviation Ctr Mission Area Analysis	ME	October
Ms Lynn Ausman Department of Nutrition Harvard Medical School Cambridge, MA	Physiology and food	ME	October
Mr. Edward Barron Individual Protection Laboratory NLABS Natick, MA	Kevlar armor effects on thermal stress	ME	October
CPT J. Belknap Chemical School FT McClellan, AL	Electrolyte balance in CW clothing	ME	October
Mr. John Bunten Shoe & Allied Trades Research Assn United Kingdom	Insulation value of footwear	ME	October
SFC Curran C. Butler SGT Robert E. LaRue 10th SFG "B" CO, 2nd Bn FT Devens, MA	Troop performance at high altitude	AR	October

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
COL William Carpenter USIDF/WRAMC Washington, DC	Assistance for Snow Eagle '82 Study - lip damage	HP	October
LTC Sheldon Dearden J-4 (Logistics) Joint Chiefs of Staff Washington, DC	Use of microclimatic cooling suits to lower body temperature of heat patients	HR	October
COL Duerr Air National Guard Minneapolis, MN	Cold weather medicine	CR	October
COL F. Erdtmann Disease Control Consultant OTSG-DASG-PSP-D Washington, DC	Temperatures inside of shelters in the desert	HR	October
MAJ Paul Gates Command Surgeon Office FORSCOM FT McPherson Atlanta, GA	Cold weather epidemiology	HP	October
Mr. Robert Kelly Individual Protection Laboratory NLABS Natick, MA	Low temperature limits for sleeping bags	ME	October
Mr. Larry Nace Morrison-Knudsen Company Boise, ID	Effects on physical per- formance of men working at 8,000 feet and living at 5,000 ft	AR	October
Mr. Painton Office of Assistant Chief of Engineering The Pentagon Washington, DC	Temperatures inside of shelters in the desert, tents vs. concrete huts	HR	October
Dr. Peter Powles, Director Intensive Care Unit Chedoke-McMaster Hospital Hamilton, Ontario Canada	Training opportunities in aviation and space medicine	AR	October
MAJ Ron Pryer Department of Epidemiology WRAIR Washington, DC	Operation Bright Star II, Egypt	HR	October

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
CPT Harold Sharp FT Richardson, AK	Cold injury to ear - data	HP	October
Mr. M. Singapore Human Engineering Laboratory Aberdeen Proving Grounds, MD	Desirable tank environment for men in MOPP 4 conditions	ME	October
Mr. David Smith Alert Mfg Co. British Columbia, CANADA	Immersion survival suit	ME	October
Mr. R.G. Smith Boeing-Vertol Inc. Philadelphia, PA	ARIEM prediction model in conjunction with B-V's contract with HEL (CW operations in Huey-Cobra)	ME	October
COL J. Stokes Academy of Health Sciences FT Sam Houston, TX	Ice requirements for cooling heat stroke patients. Also assist- ance on computer based Mid-East 3 Scenario	HR	October
Dr. Robert C. Sumner 373d Gen Hospital (USAR) Worcester, MA	Risks of air travel to patients with obstructive lung disease	AR	October
CPT David M. Terrian USAFSAM Brooks AFB, TX	LSSI Cool Vest and Cool Head Liner	ME	October
CPT Richard Travis MEDDAC FT Riley, KS	Personnel protection in frozen food warehouses	ME	October
LTC F. Tyner Neuropsychiatry Division WRAIR Washington, DC	Guidance for operations in the heat	ME	October
Dr. J. B. West University of California La Jolla, CA	Symptom questionnaire for Altitude expedition	HP	October
Mr. Arthur Woodward Human Engineering Laboratory Aberdeen Proving Grounds, MD	Energy expenditure for obstacle course	ME	October
Dr. A. D. Wright General Hospital Birmingham, England	Symptom questionnaire for Altitude expedition	HP	October

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Ms. Pat Zurenda, RN University of Colorado Boulder, CO	Symptom questionnaire for altitude research	HP	October
Mr. Ernest Blarze US Army Missile Command Redstone Arsenal, AL	Vehicle vibrations	ME	November
Dr. Edmund Burke Springfield College Springfield, MA	Analysis of anaerobic threshold using respira- tory variables	AR	November
Dr. Leo Falk Medical Director Embassy of the United States La Paz, Bolivia	Nutritional aspects of altitude sojourn	AR	November
CDR David Hall Naval Health Research Center San Diego, CA	Formation of an Extreme Thermal Environment Technical Advisory Committee	HR	November
Mr. John V. Hansen Individual Protection Laboratory NLABS Natick, MA	Effect of reduced sleeping bag insulation on sleep duration at -40°	ME	November
Dr. Wayne Hazen Department of Physics University of Michigan Ann Arbor, MI	Cosmic ray observations at high altitude	AR	November
Mr. Robert Helmbold Naval Air Development Center Warminster, PA	Heat stress - strain prediction model	ME	November
LCDR Tim Holden USH-SEAL Washington, DC	Establishing research funding to support applied projects benefiting special warfare groups exposed to environmental extremes	HR	November
Mr. Cecil Jones New Hampshire Mountain Medicine Group Worcester, MA	Symptom Questionnaire Nepal Trek	HP	November
Dr. Calvin Lee Individual Protection Laboratory NLABS Natick, MA	Assistance in preparing procurement documents for copper hand/feet	ME	November

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. Maxwell W. Lippitt, Jr. Naval Coastal Systems Center Panama City, FL	Infrared cloak	CR	November
Mr. Maxwell W. Lippitt Jr. Naval Coastal Systems Ctr Panama City, FL	Evaluation of two glove and liner systems	ME	November
Mr. Peter Macek Individual Protection Laboratory NLABS Natick, MA	Head heat loss wearing steel helmet in arctic environment	ME	November
Mr. Thomas Masciarela Quest Research Inc. McLean, VA	Air Force studies on CW contract	ME	November
COL G. McBride, Command Surgeon Ofc FORSCOM FT McPherson Atlanta, GA	Snow Eagle '82 Exercise Epidemiology	HP	November
CPT Gary McKay National Guard Bureau FT Rucker, AL	Productivity performance in an office environment and during manual materials handling	ME	November
MAJ Yancy Phillips, MC Director, Blast Over- pressure Project Department of Clinical Physiology WRAIR Washington, DC	Sickle cell trait and pulmonary function	AR	November
COL R.C. Saunders, Jr. US Army Criminal Investigation Command Seoul, Korea	Women recruits who suffer a relatively higher incidence of foot ailments during training - a solution	ME	November
MAJ Paul Theis HQDA/DASG-PSP-E Washington, DC	Water Resources Management Action Group Meeting	HR	November
Ms Joan Walker Operations Research/ Systems Analysis NLABS Natick, MA	Sleeping bag insulation and calculations; chemical protection and heat stress; copperman values for simulating nude person; prediction modeling of biophysical results of CW ensemble studies	ME	November

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
MAJ Larrence Whitehurst Division Surgeon FT Campbell, KY	Snow Eagle '82 Epidemiology	HP	November
Dr. Eugene H. Wissler University of Texas at Austin Austin, TX	Physiological heat stress on the combat soldier	ME	November
CPT Brian Wroczynski 101st Brigade Surgeon FT Campbell, KY	Snow Eagle '82 Epidemiology	HP	November
Ms. Pat Zurenda University of Colorado Boulder, CO	Measurement of subjective symptomatology of high- altitude sickness	AR	November
Mr. John Adams Westinghouse Defense Center Baltimore, MD	Ergonomics aspects of extremely cold temperature; possibilities of lung damage at -60°F, 2-min exposure with no wind	ME	December
Mr. Charles Barbe Westbaco Corp Luke, MD	Army screening tests for back problems prior to Airborne training	AR	December
Mr. Paul Cooke Quincy, MA	Hypothermia	ME	December
LTC Gerald Delaney Preventive Medicine Office OTSG Washington, DC	Protective clothing ensembles	HR	December
LTC Ralph O. DeWitt, MC Division Surgeon JFK Center FT Bragg, NC	Troop performance at high altitude	AR	December
Dr. Latham Flanagan, Jr. 655 11th Avenue East Eugene, OR	Performance measures at high altitude	AR	December
John A. Foss, Ph.D. Lincoln Center, MA	Personality factors in thermal acceptability and comfort	ME	December
Ms. Renay Glazer Allegheny College Meadville, PA	Information process, research proposal	HP	December

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. Bernard Liebman Quality Testing Co. Dix Hills, LI, NY	Insulation measurements	ME	December
Dr. Albert Moussa Arthur D. Little Co. Cambridge, MA	Residential heating - design & evaluation; fire - explosion - fuels/materials	ME	December
Ms. Mary Ellen Quinn 7845 Arlington Drive Boulder, CO	Effect of high-altitude exposure on exercise performance	AR	December
MAJ Vincent R. Sherman American Embassy APO San Francisco	Heat stress in tanks (Royal Australian Armored Corps)	ME	December
LTC V.S. Singam Asst Dir, Medical Svcs HQ 4th Division Malaysia	Clothing wear for women in Armed Forces; Physical fitness standards for males/females; effects of dehydration on perform- ance during military operations in heat and effects of heat on mental and psycho-motor performance	ME	December
COL R. Zahm C, Prev Med Activity FT Belvoir, VA	Clothing items for winter PT	ME	December
Dr. David Anderson Allegheny College Meadville, PA	Paradigms for comparing visual and auditory information processing	HP	January
LT Guy Banta, USN US Uniformed Services University of the Health Sciences Bethesda, MD	Energy cost of running	ME	January
Dr. John Berkowich DuPont Inc. Wilmington, DE	Japanese Gortex-like coating approach	ME	January
Mr. Martin Biggins Somerville, MA	Cold weather boots	ME	January
Dr. John M.R. Bruner Anesthesia Dept. Massachusetts General Hospital Boston, MA	R-Value of skin with reference to severely burned adults	ME	January

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. James R. Durfee Cabin John, MD	Inherited susceptibility to cold injuries	ME	January
Dr. P. Dennison Burlington, VT	Problem and recommenda- tions of pernio (condition which occurs in feet - coolness and dampness)	ME	January
LTC Manuel Garcia FT Hood, TX	Cold weather epidemiology	HP	January
COL Joel Gaydos PT 10th Med Lab Landstuhl, Germany	Formulation of SOPs for cold weather	ME	January
Dr. C. Gray Naval Submarine Research Laboratory Groton, CT	Vapor barrier boots	ME	January
Mr. Vince Griffin Public Service Indianapolis, IN	Hypothermia	ME	January
Mr. Charles Hickey, Jr. Human Engineering Laboratory Aberdeen Proving Grounds, MD	Energy expenditures	ME	January
Prof. Ingvar Holmer Dept. of Occupational Health Nat'l Board of Occupational Safety and Health Solna, Sweden	Thinsulate - insulating material	ME	January
Mr. Joseph Kerry Herald American Boston, MA	Cold discomfort	ME	January
MAJ G. Krueger USAMRDC FT Detrick Frederick, MD	Heat stress from a point of view of a physician	ME	January
Mr. John Kussman Vaisla Corp. Woburn, MA	Humidity measuring instruments	ME	January
Mr. Frederic S. Langa, Editor Rodale's NEW SHELTER Emmaus, PA	Correlating temperature, air speed, humidity and exertion	ME	January

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. Harry Levine, Jr. General Electric Washington, DC	Symptom Questionnaire	HP	January
Lou Adler's Medical Journal WOR-Radio New York, NY	Precautions against cold	ME	January
Mr. H. Madnick Individual Protection Laboratory NLABS Natick, MA	Clo values of 3-finger glove	ME	January
CPT R. Margulies US Uniformed Services University of the Health Sciences Bethesda, MD	Water immersion and whole body cooling	ME	January
Dr. R. Marlow WRAIR Washington, DC	Troops jumping into cold and precooling the aircraft	ME	January
Dr. Malcolm Pluskal Boston Biomedical Research Institute Boston, MA	Respiratory muscle fatigue during exercise at altitude	AR	January
Ms. Robin Reilly Dover, MA	Prevention and treatment of acute mountain sickness and pulmonary edema	AR	January
Mr. Douglas Scruton Ayer, MA	Cold weather boots	ME	January
Dr. Ulla-Maarit Saari Dept. of Textile & Clothing Technology Tampere University of Technology Finland	Cold headwear	ME	January
LTC Gene Suggs National Guard Safety Ofc Washington, DC	Air Force mukluks for Guard pilots	CR	January
Ms. Christine Temin Boston Globe Boston, MA	Article on nutritional requirements in the cold	CR	January

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Prof. Frederick L. Test Department of Mechanical Engineering & Applied Mechanics University of Rhode Island Kingston, RI	Clothing insulation	ME	January
COL Michael R. Antopol US Army Surgical Consultant The Pentagon Washington, DC	Hypoxia-induced medical disabilities	AR	February
Mr. Glenn Berckman US Army Health Clinic Watervliet Arsenal, NY Watervliet, NY	Workers entering extremely cold rooms to check dials - short periods; cold stress possibilities	ME	February
LTC Robert Chloupek Surgeon's Office DARCOM Alexandria, VA	Mobile protected gun - water requirements	ME	February
Mr. Michael Crowley National Fisherman Magazine Camden, ME	Cold weather protection and feeding	ME	February
Dr. L. Flanagan, Jr. College of Surgeons Eugene, OR	Assessing performance with electrical games	HP	February
Ms Laurel Gilbright Reader's Digest New York, NY	Ice vests	ME	February
MAJ H. Hano MEDDAC FT Leonard Wood, MO	Wind chill (formulas for calculating)	ME	February
CPT A. Hinch HQS USAF/SAGP The Pentagon Washington DC	Heat stress prediction model with reference to CW	ME	February
CPT R. Hood Tyndall AFB, FL	WGT measurements	ME	February
LTC William Lam, MC FT Irwin, CA	Desert injuries	HP	February
BG F. Ledford, Jr. Director of Professional Services The Pentagon Washington, DC	Medical and performance problems at high terres- trial elevations	AR	February

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
CPT Lawrence Lynch 223 Medical Det. FT Carson, CO	Cold injuries	ME	February
Dr. Henry Manson Department of Anesthesia Memorial University St. John, Newfoundland, Canada	Survival suits for oil drilling platforms	ME	February
Mr. Charles Orloff School Committee Dennis-Yarmouth School District Dennis, MA	Wind chill effects - freezing point of skin	ME	February
LTC Reddington Health Services Medical School FT Sam Houston, TX	Cold adaptation protocol	CR	February
Ms Laurie Rosen Individual Protection Laboratory NLABS Natick, MA	Anti-exposure suit protection	ME	February
COL J. H. Rumbaugh C, Medical Corps Career Activities Office AMEDDPERSA Washington, DC	Biomedical aspects of high-altitude exposure	AR	February
Dr. Ernie Sachs Dartmouth, NH	Capabilities of DMSO	CR	February
Mr. John W. Stephenson Gilford, NH	Metallized layers in clothing systems	ME	February
Mr. Mel Allen Yankee Magazine Auburn, ME	Survival time in 35°F water temperature in fast flowing river	ME	March
CPT Curtis K. Bayer C, Tactical Systems Div ACS/Studies and Analyses HQS USAF Washington, DC	Proper values and equations in calculating heat loss rates with reference to personnel efficiency loss (CW ATTACK)	ME	March
Gordon A. Benner, M.D. 3000 Colby Street Berkeley, CA	Preacclimatization of soldiers to high altitude	AR	March

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
LTC Jerry M. Brown International Health Affairs Director The Pentagon Washington, DC	Prevention and treatment of heat injuries	HR	March
COL Francis J. Cadigan, Jr DAO-AMLO US Embassy APO, NY	Altitude-related medical and performance problems	AR	March
H. M. John Cahill US Navy Reserve Worcester, MA	Combat stress information	HP	March
LTC Charles Clark Vicenza MEDDAC APO NY	Problems of heat illness	HR	March
Ken C. Elam, M.D. Stateline Emergency/ Outpatient Services Stateline, NV	Nocturnal oxygen therapy in the prevention of high-altitude pulmonary edema	AR	March
COL F. Erdtmann Disease Control Consultant OTSG-DASG-PSP-D Washington, DC	Safety limits for exposure to hot/dry wet saunas	HR	March
Mr. Robert Foust Office of Senator Pell Washington, DC	Modifications for thermal comfort of the elderly with clothing	ME	March
MAJ Jess Fulfer RDJTF, Surgeons Ofc MacDill AFB, FL	Gallant Eagle '82	HP	March
Dr. T.J. Gallwey Department of Mechanical & Production Engineering The National Institute for Higher Education Limerick, Ireland	Bivariate frequency tables for US Army men and women	ME	March
CPT Kent Halstead The Pentagon Washington, DC	Changes in convective and evaporative cooling with wind and body motion	ME	March
Mr. W.R. Hindson Head, Textiles Technology Department of Defence Materials Research Laboratories Maribyrnong, Victoria Australia	Guarded hot plate updating	ME	March

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
COL J. James Academy of Health Sciences FT Sam Houston, TX	Gallant Eagle '82	HP	March
Mr. Peter Judd Luray, VA	Training in hot weather	ME	March
LTC J.D. LaMothe USAMRDC FT Detrick Frederick, MD	Gallant Eagle '82	HP	March
LTC J.D. LaMothe USAMRDC FT Detrick Frederick, MD	Botsball information	ME	March
CPT P. O'Brien FT Leonard Wood, MO	BDU Uniform/heat stress	ME	March
MAJ J. Poplin HQS, Air Force Tactical Air Command Langley AFB, VA	Heat stress characteristics of work uniform in hot environments; required parameters for new desert uniform	ME	March
Dr. R. Roth Individual Protection Laboratory NLABS Natick, MA	Ability of semi-permeable material to evaporate secreted sweat	ME	March
Dr. George Schirow Department of Industrial Engineering State University of New York at Buffalo Amherst, NY	Hot wire anemometer	ME	March
COL George Stebbing Occupational Health Consultant Preventive Medicine Office OTSG Washington, DC	Use of salt tablets and treatment of heat injuries	HR	March
Mr. Christopher F. Teniswood Occupational Health Section Mount Isa Mines Ltd Mount Isa, QLD 4825 Australia	Problems of heavy load carriage	ME	March
COL Arthur Terrill, MC RDJTF Command Surgeon MacDill AFB, FL	Gallant Eagle '82 - injury reports	HP	March

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. Alex Weisz Hughes Aircraft Inc Canoga Park, CA	Auxiliary cooling in varied environments	ME	March
Mr. Fred Williams Moonstone, Inc. Arcata, CA	Effectiveness of vapor barriers for cold weather clothing or sleeping systems	ME	March
Mr. Robert Bohi HQS TRADOC FT Monroe, VA	Botsball weather monitoring device	ME	April
CPT. P. Chambers Preventive Medicine Activity FT Jackson, SC	WBGT guidance for training in MOPP 4 CW clothing	ME	April
Dr. Lloyd Crumley Army Research Institute FT Sill, OK	Field Artillery Crew Test	HP	April
Mr. Harvey Daigle Individual Protection Laboratory NLABS Natick, MA	Heat stress/discomfort in body armor	ME	April
LTC Gerald Delaney Preventive Medicine Office OTSG Washington, DC	MOPP gear	HR	April
LTC Gerald Delaney Preventive Medicine Office OTSG Washington DC	Chemical suits - heat stress, men vs women	ME	April
Cdr Robert Devine C, Radiological Physics Div Armed Forces Radiology Research Institute Bethesda, MD	Cooling vests (ice packets water cooled) and radiation protection	ME	April
Mr. Guy Dirkin Motor Behavior Lab University of Illinois Champaign, IL	Cognition during stress	HP	April
Mr. M. Donnheiser M. Lowenstein Co. Lyman, SC	Fabric insulation	ME	April
National Fisherman Magazine Camden, ME	Cold water survival suits	CR	April

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. Latham Flanagan, Jr Eugene, OR	Intellectual and judgment performance deterioration at high elevations	AR	April
MAJ William Gifford TRADOC FT Jackson, SC	Botsball	ME	April
LCDR Charles G. Gray Naval Health Research Center San Diego, CA	Computer simulation models of the human physiological system; predicting human performance under varying environmental conditions with overlays of exercise, sleep deprivation and nutrition	ME	April
Dr. Donald Henry Lake City, SC	Windchill	ME	April
Ms Barbara Kirkwood Individual Protection Laboratory NLABS Natick, MA	Evaluations of proposals for design of biophysical test devices	ME	April
MAJ Charles Kirkwood Personal Protection Branch FT McClellan, AL	CW Overgarment (ILC Dover)	ME	April
MAJ G. Krueger USAMRDC FT Detrick Frederick, MD	Radiant heating of cold-soaked tanks	ME	April
MAJ D. Kowal DCSOPS The Pentagon Washington, DC	Military clothing (except CW)	ME	April
Mr. M. Markel Markel Electric Products, Inc Buffalo, NY	MRT Sensors	ME	April
Dr. Richard T. Meehan Division of Rheumatology Department of Internal Medicine University of Iowa Hospitals and Clinics Iowa City, IA	Prostaglandins and circu- latory responses to high altitude	AR	April
Dr. Karen Neff ARI Field Unit FT Leavenworth, KS	Sustained operations	HP	April

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
LTC C. Prickett DCSLOG The Pentagon Washington, DC	WBGT stress indices	ME	April
Charles Rader Gillette Company Boston, MA	Frostbite injury in regard to sweat suppressant deodorants	CR	April
Dr. Leo C. Senay, Jr Department of Physiology St. Louis University Medical Center St. Louis, MO	Antidiuretic hormone and fluid shifts at high altitude	AR	April
LTC D. Schnakenberg Nutrition Staff Officer USAMRDC The Pentagon Washington, DC	Meeting with NATO group in May	HR	April
Mr. Paul Smith Army Times News Service Washington, DC	Army cold weather clothing	ME	April
Prof. John Spargo Northeastern University Boston, MA	Body composition work	ME	April
COL Eloise Strand Personnel Policies-PTB The Pentagon Washington, DC	Difference in heat tolerance between females and males	ME	April
Dr. Brian Whipp University of California Medical Center Harbor Hospital Torrance, CA	Upper body exercise	ME	April
Mr. James Bevelock Cannon Artillery System AARADCOM Dover, NJ	Troop fatigue with reference to new howitzer under development	ME	May
Mr. Dick Brown Athletics West Boston, MA	Boston Marathon	HR	May
Dr. Ari Brynjolfsson Science and Advanced Technology Laboratory NLABS Natick, MA	Microclimate cooling	ME	May

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. Robert Chessin Mr. Donald Johnston Triangle Research Institute Durham, NC	Army research program in high altitude physiology and medicine	AR	May
Ms N. Clark Sports Medicine Resource Ctr Boston, MA	Requirements for channel swimming	ME	May
Mr. Joseph Cohen Individual Protection Laboratory NLABS Natick, MA	Cold weather protection in tanks	ME	May
Dr. Edward H. Cornell Institute of Child Development University of Minnesota Minneapolis, MN	Rate of locomotion and endurance in natural environments	ME	May
Dr. Linda Crockett Boulder, CO	Evaluation of symptom severity at high altitude	AR	May
SGT Ellison Preventive Medicine Unit FT Irwin, CA	Hot weather briefings, fluid consumption levels, and advisability of caffeinated vs. non-caffeinated beverages, advisability of carbonated vs. non-carbonated beverages for consumption in the field	HR	May
COL F. Erdtmann Disease Control Consultant OTSG-DASG-PSP-D Washington, DC	Medical Circular	HR	May
Dr. L. Flanagan, Jr. College of Surgeons Eugene, OR	Review grant proposal: Assess performance during a mountain climb	HP	May
Mr. J. Fratantuono Individual Protection Laboratory NLABS Natick, MA	Insulation conversions (to K) for auxiliary cooling suit design	ME	May
Mr. Harold L. Gotoff A/Chief, Phys Prot Br USAARDC Chemical Systems Laboratory Aberdeen Proving Grounds, MD	Hood-Jacket accessory for M23A1 breathing apparatus	ME	May

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. M. Herz Operations Research/ Systems Analysis NLABS Natick, MA	Potential for relieving heat stress	ME	May
Dr. T. Scott Johnson Pulmonary Unit Beth Israel Hospital Boston, MA	Brain tissue hydration at high altitudes	AR	May
Dr. Sukhamay Lahiri Institute for Environmental Medicine University of Pennsylvania Philadelphia, PA	Arterial oxygen desatu- ration during sleep at high altitudes	AR	May
Dr. Wouter A. Lotens Institute for Perception (TNO) The Netherlands	Evaluations of body armor	ME	May
CPT R. Morales FT Carson, CO	Panama training - prediction for heat stroke	ME	May
Mr. H. Rieck West German Air Force Medical Institute Federal Republic of West Germany	Modeling collaborations	ME	May
Prof. M.L. Riedesel Department of Biology The University of New Mexico Albuquerque, NM	Heat injuries	ME	May
Ms Wendy Shapiro Doremus Co. New York, NY	Footwear health and shoes	ME	May
Mr. Daniel F. Shimkus Engineering Program Management Office NLABS Natick, MA	Review of draft test operations procedure (TOP) 10-3-511, Cold test of sleeping equipment	ME	May
COL Warner Water Resources Management Group Washington, DC	Meeting of Water Resources Management Action Group at FT Belvoir, VA	HR	May
Dr. Roy Widdes Food Nutrition Board National Academy of Sciences Washington, DC	Potassium losses in sweat of Marines wearing protective clothing	ME	May

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. Roy Widdes Food Nutrition Board National Academy of Sciences Washington, DC	Workshop and Board Meeting 3-4 June	HR	May
Dr. Barbara Avellini Navy Clothing and Textile Research Facility Natick, MA	Symptom Questionnaire - marine study	HP	June
Dr. Charles Babbs A.A. Potter Engineering Center Purdue University Lafayette, IN	Development of a hypo- hydration assessment device	HR	June
Ms Sharon Beckman Cambridge, MA	English Channel swimming	ME	June
Mr. Frank Carol OSHA Cincinnati, OH	Worker comfort and wearing of protective clothing	ME	June
COL R. Crochet, USAF Offutt AFB Omaha, NE	Evaluations on North Face vacuum-packed bags (B-1 survival kit)	ME	June
Mr. Steve Ehrick Aerotherm Corp Anaheim, CA	Thermal stress in an NBC environment	ME	June
Mr. Michael F. Fisette Systems Integration Division USAMDRC Dover, NJ	Division support weapon system	ME	June
Dr. M. A. Frey Tech Dir, Physiology and Clinical Chem Lab NASA Space Rsch Center Cape Kennedy, FL	Gas analysis instrumentation	AR	June
MAJ Gulbrandsen USAEHA/HSSB-OM Aberdeen Proving Grounds, MD	Heat stress standards for DPD personnel	HR	June
MAJ John Herbold Disease Surveillance Branch Epidemiology Division School of Aerospace Medicine Brooks AFB, TX	Instruments for the assessment of mountain sickness symptoms	AR	June

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
MAJ Stanley Holgate Fort Ord Monterey, CA	Intellectual performance at high altitudes	AR	June
ILT Mark Holtzapple Science and Advance Technology Laboratory NLABS Natick, MA	Review on a chemical agent protective garment	ME	June
Mr. Jack Galub New York, NY	Man in the cold - general problems; freezing of the extremities, man's major protection against cold	ME	June
LTC Fred Isrig TECOM Aberdeen Proving Grounds, MD	Auxiliary cooling	ME	June
Dr. Daniel Kimball WRAIR Washington, DC	Hematic changes with MOPP gear	ME	June
Mr. Al Kotz US Coast Guard Washington, DC	Assistance in preparation of Coast Guard heat stress standard	ME	June
LTC Charles Lesko HQS TRADOC FT Monroe, VA	Torso clothing and insulation	ME	June
Mr. John Matloch Department of Landscape Architecture Texas A&M University College Station, TX	Assessment of thermal comfort	ME	June
Mr. Nick Montanarelli DARCOM Alexandria, VA	BDU uniform	ME	June
Mr. Earl Munser Chemical Systems Laboratory Aberdeen Proving Grounds, MD	Evaluation of new M-18 head wound mask	ME	June
MAJ Peter Myers US Army Nuclear & Chemical Agency Springfield, VA	Thermal stress while wearing CW protective clothing	ME	June
Dr. Benjamin G. Newman Altamonte Springs, FL	Marine Reserve heat stress - water requirements	ME	June

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. S. O'Donnell Academy of Health Services FT Sam Houston, TX	Air Force Bulletin information on Botsball	ME	June
LTC D. Schnakenberg USAMRDC The Pentagon Washington, DC	Helly Hansen CW protective overgarment; underwater weighing techniques	ME	June
Ms Marie Swierstra South African Science Office Beverly Hills, CA	Instrumentation for WBGT/WGT Indices of thermal stress	ME	June
Dr. M. Tankleff Consolidated Troop Clinic Wm Beaumont Army Med Ctr El Paso, TX	Heat tolerance	ME	June
Mr. Jan Van Duser Director of Operations The National Football League New York, NY	Guidelines for men exposed to extreme cold	ME	June
Mr. William Wanger FMC Corporation San Jose, CA	Heat casualty prediction and microclimate cooling	ME	June
MAJ J.D. Winchester Combat Service Support Instr. Division Amphibious Instruction Department Education Center Quantico, VA	Material for briefing to USMC Command Staff College	HR	June
Dr. Donald Wodtli FT Leonard Wood, MO	Current heat research programs within the Army.	HR	June
Mr. David Abrahamson Backpacker Magazine New York, NY	Effects of cold and exertion in the cold; USARIEM study of cross country skiing	ME	July
COL R. Barranco, MC Maryland National Guard Baltimore, MD	Heat problems of the National Guard	ME	July
Dr. Bowles DARCOM (DRC-DESA) Alexandria, VA	Heat stress and performance	HR	July

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Dr. F. Duane Blume Department of Biology California State College Bakersfield, CA	Fat absorption at high altitudes	AR	July
Dr. Nathaniel Carleton Harvard Smithsonian Center for Astrophysics Boston, MA	Human problems involved in operating observatories at altitude	HP	July
Dr. Nathaniel Carleton Harvard Smithsonian Center for Astrophysics Cambridge, MA	Performance decrements at high altitude	AR	July
Mr. Keith Carson PMO-MI Tank System Warren, MI	Weather extremes	ME	July
Dr. David Cudaback Astronomy Department University of California Berkeley, CA	Human problems involved in operating observatories at altitude	HP	July
Dr. David Cudaback Astronomy Department University of California Berkeley, CA	Performance decrements at high altitude	AR	July
Mr. Peter Davis Athletics West Eugene, OR	Heat problems of the marathoner	ME	July
Dr. Robert Dunn Eye and Ear Hospital Pittsburgh, PA	Editing and publication of Lancer Eagle report in Military Medicine	HR	July
MAJ David Gilhooly Department of Neuropsychiatry School of Aerospace Medicine San Antonio, TX	Assessment of acute mountain sickness symptoms	AR	July
Dr. Norman Hollies University of Maryland College Park, MD	Comfort research	ME	July
Mr. Bowen Huntsman EG&G Corporation Shelleg, ID	Heat stress wearing protective clothing	ME	July
Mr. James E. Larsen Training Development Institute FT Monroe, VA	Army heat injury tasks; Botsball heat stress training programs	ME	July

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Ms Cathy Lee TECOM Aberdeen Proving Grounds, MD	Protective characteristics of aircrew clothing; ARIEM tests on waterproof anti-exposure suits; ROC for aircrew clothing	ME	July
Dr. Alexander Lind Department of Physiology St. Louis University School of Medicine St. Louis, MO	Heat stress and heat stroke	HR	July
SGT W. Lutyens Survival School Fairchild AFB Spokane, WA	Revision of Survival Manual 64-3; infrared photographs - aircrew clothing	ME	July
Dr. Owen Maller Science & Advanced Technology Laboratory NLABS Natick, MA	Questionnaires - field study	HP	July
BG Robert M. Montague USA Rtd Special Olympics Inc. Washington, DC	Assistance in planning for 1983 Special Olympics, Baton Rouge, LA	ME	July
Barbara Posner, D.P.H., R.D. Department of Health Science Boston University Boston, MA	Adolescent obesity	ME	July
COL M. Ranadive Preventive Medicine Office OTSG Washington, DC	Ontario Canada based instrument Company manufacturing a Botsball-like device for the USN (Reuter-Stokes)	HR	July
Dr. Barbara Sandick Science & Advanced Technology Laboratory NLABS Natick, MA	Symptom Questionnaire - Heat study	HP	July
LTC D. Schnakenberg Nutrition Staff Officer USAMRDC The Pentagon Washington, DC	Regarding on-going research in heat, also DA Heat Circular	HR	July

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SSG Kevin Sheff Prev Med Activity 42nd Div (Nat'l Guard) FT Drum, NY	Review of heat casualties during training	ME	July
Mr. O. Svaeri MERADCOM FT Belvoir, VA	Microclimate cooling	ME	July
Dr. Daniel Welch Andrulis Research Corp. Bethesda, MD	Dugway heat stress CW field test	ME	July
Dr. Roy Widdes National Academy Science & Food Nutrition Washington, DC	Committee on nutritional requirements for personnel wearing protective clothing	HR	July
CDR Dennis Wright Arkansas College Batesville, AR	Briefing material on heat illnesses and problems in the heat	HR	July
SP6 McLintock 4th Infantry Div (Mechanized) FT Carson, CO	Acetazolamide prophylaxis against acute mountain sickness	AR	August
Mrs Brenda Brandt School of Home Economics University of Arizona Tucson, AZ	Principles and applica- tion of clothing design for desert climates	ME	August
Dr. Paul Buchanan, Director Research Support Branch NASA Space Research Center Cape Kennedy, FL	Body composition variation with gender, age and body type; physiological measures of stress during space flight	AR	August
CPT Deidre Christenberry Cdr, 223rd Med Detachment FT Carson, CO	Physical training women attached to 4th Mechanized Infantry	ME	August
Mr. Kenneth Harmon DIA FT Sill, OK	Reduction in heat stress by painting helmets white - proposed ARIEM test	ME	August
Dr. Patrick Potter BDM Corporation McLean, VA	Heat stress on men performing runway repairs in hot environments	ME	August

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Mr. Carl Thayer USAMRDC FT Detrick Frederick, MD	Auxiliary heat requirements for heated casualty evacuation bag	ME	August
Dr. S. K. Sensarma Central Labour Institute Ministry of Labour Sion, Bombay India	Development of personal protective clothing for workmen exposed to process heat	ME	August
Dr. John R. Sutton Department of Medicine McMaster University Hamilton, Ontario Canada	Spironolactone and acute mountain sickness	AR	August
MAJ John Szurek C, Info Sci Div. USAMRDC FT Detrick Frederick, MD	Behavioral instrumentation	HP	August
LTC William Alter, III Physiology Department US Uniformed Services University of the Health Sciences Bethesda, MD	Heat stress and CW clothing temperature measurements	ME	September
Dr. Forst Brown Dartmouth Medical School Hanover, NH	Raynaud's treatment	HP	September
Dr. Robert C. Carter Naval Biodynamics Lab New Orleans, LA	USARIEM Behavioral Task Battery	HP	September
Children's TV Workshop (3-2-1 Contact) New York City, NY	Filming of Dr. Hamlet for children's program dealing with cold	CR	September
Dr. Barbara Edelman-Lewis Science and Advanced Technology Laboratory NLABS Natick, MA	Performance assessment with PETER tasks	HP	September
Ms Monica Glumm Human Engineering Laboratory Aberdeen Proving Grounds, MD	Crew ventilation in armored personnel carriers	ME	September

<u>Requesting Individual/Agency</u>	<u>Subject</u>	<u>Division</u>	<u>Month</u>
Mr. David Ingram TRADOC FT Monroe, VA	Botsball; calculating comfort from clo and im/clo; biophysical evaluation of TBDU	ME	September
Mr. Phil Mueller CDS Systems Denver, CO	Instrumentation for psychology labs	HP	September
Dr. Martha D. McDaniel Northwestern Memorial Hospital Chicago, IL	Raynaud's treatment	HP	September
LTC Gerald Mindrum USAMEDDAC APO Miami, FL	Botsball instrumentation	ME	September
CPT R. Monin US Army Cold Regions Test Center APO Seattle, WA	Water immersion studies	ME	September
Dr. Harker Rhodes Department of Medical Pathology University of Pennsylvania Philadelphia, PA	High density lipoprotein levels in plasma from altitude-exposed subjects	AR	September
Dr. Barbara Sandick Science & Advanced Tehnology Laboratory NLABS Natick, MA	Cognitive assessment	HP	September
Dr. Gary M. Whitford Department of Oral Biology- Physiology Medical College of Georgia Augusta, GA	Effects of anesthesia on the respiratory responses to hypoxemia	AR	September

APPENDIX E  
BRIEFINGS

Francesconi, R. Diet and physical performance: Water and salt. Joint Formulation Board for Food Research Development Technology and Engineering, RDT & E, NLABS, Natick, MA, May 1982.

Francesconi, R. Prevention of heat injury. Cutler Army Hospital, Ft. Devens, MA, May 1982.

Goldman, R. Heat stress, the association with various uniforms (the Battle Dress Uniform in particular and the heat stress problem). MG Blount, TRADOC, Ft. Monroe, VA, April 1982.

Goldman, R. Heat Stress and the Battle Dress Uniform. MG Akers, Ft. Jackson, SC, April 1982.

Goldman, R. Male-Female Clothing Comfort (CW). LTG J.H. Merryman, Deputy Chief of Staff for Research, Development and Acquisition, The Pentagon, Washington, DC, June 1982.

Goldman, R. Comparative heat stress in CW with the Battle Dress Uniform. General Officers, The Pentagon, Washington, DC, June 1982.

Goldman, R. Microclimate cooling. Commanding General, TRADOC, Ft. Monroe, VA, July 1982.

Hamlet, M.P. Cold weather preventive medicine. Troops, Ft. Devens, MA, October 1981.

Hamlet, M.P. Cold weather aviation. Safety Personnel, Ft. Devens, MA, October 1981.

Hamlet, M.P. Cold weather preventive medicine. Troops, Ft. Devens, MA, October 1981.

Hamlet, M.P. Cold weather preventive medicine. Biomedical Impact of Extreme Environments Seminar, NAVSPECWARGRU ONE, San Diego, CA & Port Hueneme, CA, November 1981.

Hamlet, M.P. Prevention of cold injury. Flight Surgeon's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, November 1981.

Hamlet, M.P. Cold weather medicine. Physicians, Cutler Army Hospital, Ft. Devens, MA, November 1981.

Hamlet, M.P. Cold weather preventive medicine. Special Forces Group, Ft. Devens, MA, January 1982.

Hamlet, M.P. Cold weather preventive medicine. Marine Reserve Unit, Hartford, CT, January 1982.

Hamlet, M.P. Cold weather preventive medicine. National Guard Reserve Unit, Bangor, ME, February 1982.

Hamlet, M.P. Cold weather preventive medicine. 10th Annual Safety Conference, Army Aviation Support Facility - BIA, Bangor, ME, February 1982.

Hamlet, M.P. Cold weather preventive medicine. 25th Infantry Division, Schofield Barracks, HI, February 1982.

Hamlet, M.P. Cold weather preventive medicine. Flight Surgeon's Course on Temperature Extremes, USAAMED Center, Ft. Rucker, AL, March 1982.

Hamlet, M.P. Cold weather preventive medicine. Aviation personnel, Massachusetts Army National Guard Safety Management School, Sturbridge, MA, March 1982.

Hamlet, M.P. Cold weather preventive medicine. Naval Support Force Antarctica Cold Weather Medicine Conference, Port Hueneme, CA, August 1982.

Hamlet, M.P. Cold weather preventive medicine. Flight Surgeon's Course on Temperature Extremes, USAAMED Center, Ft. Rucker, AL, August 1982.

Hubbard, R.W. Heat illness and ice: Problems and solutions. Water Resources Management Action Group, Army Logistics Center, Ft. Lee, VA, 21 October 1981.

Hubbard, R.W. Biomedical consequences of extreme thermal environments. Port Hueneme, CA, November 1981.

Hubbard, R.W. Water as a tactical weapon. COL Dewitt, Surgeon JFK Center, Ft. Bragg, NC, December 1981.

Hubbard, R.W. Water requirements in hot and cold and arid environments. Nick Montanarelli, FEL, NLABS, Natick, MA, January 1982.

Hubbard, R.W. Water and salt relationships to military performance. Research and Development Associates, Chicago, IL, April 1982.

Hubbard, R.W. Aspects of heat injuries. Cutler Army Hospital, Ft. Devens, MA, May 1982.

Hubbard, R.W. Prevention of heat injury. Cutler Army Hospital, Ft. Devens, MA, May 1982.

Hubbard, R.W. A survey of information related to drinking water requirements in hot climates. Second Water Resources Management Action Group Meeting, Ft. Belvoir, VA, May 1982.

Hubbard, R.W. Water as a tactical weapon: A doctrine for prevention of heat casualties. WRAIR, Washington, DC, May 1982.

Hubbard, R.W. Optimal fluid/nutritive requirements for troops operating for more than 6 hours in chemical protective gear. National Academy of Sciences, Washington, DC, June 1982.

Hubbard, R.W. Operations in the heat and Heat illnesses. Operational Readiness Training Course, Naval School of Health Sciences, National Naval Medical Center, Bethesda, MD, June 1982.

Hubbard, R.W. Water requirements during hot weather operations. LTG Becton, MG Oblinger, MG Brown, MG Rapmund and BG Drummond, TRADOC, Ft. Monroe, VA, September 1982.

Hubbard, R.W. Use of small mobile chiller to cool heat casualties. 18th Airborne Corps, OTSG and RDJTF, MERADCOM, Bolling AFB, Washington, DC, September 1982.

Levell, C.A. Tri-service aeromedical research panel (TARP) Tech. Mtg., Brooks Air Force Base, TX, October 1981.

Mager, M. Problems in the heat. Flight Surgeon's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, November 1981.

Mager, M. Problems in the heat. Flight Surgeons's Course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, March 1982.

Vogel, J. MEPSCAT validation. BG Zeltman, DAPE-ZAW, 16 August 1982

Vogel, J. MEPSCAT validation. BG Edmonds TRADOC, 19 August 1982.

APPENDIX F  
LECTURES

Burse, R.L. Renal physiology. Boston University, Sargent College of Allied Health Professions, Boston, MA, 12 November 1982.

Burse, R.L. Regulation of body fluid volume and composition. Boston University, Sargent College of Allied Health Professions, Boston, MA, 17 November 1982.

Burse, R.L. Acid-base balance. Boston University, Sargent College of Allied Health Professions, Boston, MA, 19 November 1982.

Daniels, W.L. Overview of USARIEM. Doctoral Luncheon. Springfield College, Springfield, MA, 18 March 1982.

Goldman, R.F. Fitness, nutrition and weight regulation. Presented before the Boston Area Dieticians, US Army Research Institute of Environmental Medicine, Natick, MA, 27 October 1981.

Goldman, R.F. Atmospheric environment in the workspace. Workspace Design. University of Wisconsin, Madison, WI, 10 December 1981.

Hamlet, M.P. Hypothermia and near drowning. The Mercy Hospital of Johnstown, PA, 12 November 1981.

Hamlet, M.P. Field management of cold injuries. Stow Fire Department, Stow, MA, 17 November 1981.

Hamlet, M.P. Frostbite and Hypothermia. Appalachian Mountain Club, Boston, MA, 19 November 1981.

Hamlet, M.P. Hypothermia and cold weather drowning. Emerson Hospital, Concord, MA, 25 November 1981.

Hamlet, M.P. Cold injury. Physicians. Nepal, 26-30 November 1981.

Hamlet, M.P. Cold weather preventive medicine. Holderness School, Plymouth, NH, 12 January 1982.

Hamlet, M.P. Cold water drowning. Boston Childrens Hospital, Boston, MA, 20 January 1982.

Hamlet, M.P. Cold water drowning and hypothermia. Emerson Hospital, Concord, MA, 27 January 1982.

Hamlet, M.P. Medical management and treatment of hypothermic patients. Cape Cod & Islands EMS Hypothermia Workshop, Hyannis, MA, 29 January 1982.

Hamlet, M.P. Hypothermia and cold water drowning. Leonard Morse Hospital, Natick, MA, 4 February 1982.

Hamlet, M.P. Cold water drowning. Critical Care Nursing Seminar, Woburn, MA, 9 February 1982.

Hamlet, M.P. Hypothermia and drowning. Sports Medicine Conference, Lake Placid, NY, 17-18 February 1982.

Hamlet, M.P. Hypothermia and cold water drowning. Dartmouth Hitchcock Medical Center, Fairlee, VT, 21 February 1982.

Hamlet, M.P. Hypothermia and near drowning. Baystate Medical Center, Springfield, MA, 6 March 1982.

Hamlet, M.P. Hypothermia, frostbite, and drowning. Conemaugh Valley Memorial Hospital, Johnstown, PA, 8 March 1982.

Hamlet, M.P. Hypothermia and cold water drowning. St. Joseph's Hospital, Nashua, NH, 11 March 1982.

Hamlet, M.P. Field management of cold injuries. Pownal Fire Department and Rescue Squad, Pownal, Vermont, 17 March 1982.

Hamlet, M.P. Hypothermia and near drowning. Concord Hospital, Concord, NH, 6 April 1982.

Hamlet, M.P. Hypothermia. Bellows Falls, VT, 20 April 1982.

Hamlet, M.P. Hypothermia. Monadnock Community Hospital, Peterborough, NH, 30 April 1982.

Hamlet, M.P. Cold weather preventive medicine. North Atlantic Region of the American Society Extracorporeal Technology, Boston, MA, 12 June 1982.

Hamlet, M.P. Hypothermia and near drowning. Beth Israel Hospital, Boston, MA, 23 June 1982.

Hamlet, M.P. Lecture on hypothermia and near drowning. YMCA, Marblehead, MA, 26 June 1982.

Hamlet, M.P. Cold injury. National Science Foundation Antarctic Deployment Program, Reston, Va, 14 September 1982.

Hamlet, M.P. Trenchfoot, frostbite and hypothermia. Veterans Administration Medical Center, Northampton, MA, 22 September 1982.

Jobe, J.B. Behavioral Treatment for Raynaud's Disease. Harvard Medical School, Boston, MA, June 1982.

Jones, B.H. Review of the anatomy of the lower extremity and common causes of overuse injuries to this area. Wellesley College, Wellesley, MA, 18 November 1981.

Jones, B.H. Causes of lower extremity injuries secondary to physical training in military populations. Grand Rounds, Lyster Army Hospital, Ft. Rucker, AL, 19 March 1982.

Knapik, J.J. Serum substrate changes during exercise with caffeine. Graduate Seminar in Striated Muscle, Boston University, Boston, MA, April 1982.

Maher, J.T. Physiological, medical and performance aspects of high-altitude exposure. Special topics seminar: Exercise and Environment. Department of Health Sciences, Boston University, Boston, MA, 6 April 1982.

Pandolf, K.B. Environmental influences on exercise: Effect of heat, cold and altitude. Seminar in exercise physiology. University of Pittsburgh, Pittsburgh, PA, 15 October 1981.

Pandolf, K.B. Energy expenditure and load carriage. Human Energy Research Laboratory, University of Pittsburgh, Pittsburgh, PA, 16 October 1981.

Pandolf, K.B. Altitude and climate in sports. Sports medicine and athletic training lecture. Massachusetts Maritime Academy, Buzzards Bay, MA, 16 and 23 July 1982.

Pandolf, K.B. Altitude and climatic considerations during exercise: An overview. Special topics seminar: Exercise and Environment. Boston University, Boston, MA, 26 January 1982.

Pandolf, K.B. Individual factors which alter human physiological responses during exercise in the heat. Special topics seminar: Exercise and Environment. Boston University, Boston, MA, 16 February 1982.

Patton, J.F. Human performance in the cold. Special Topics Seminar: Exercise and Environment. Sargent College of Allied Health Professions, Boston University, Boston, MA, 20 April 1982.

Sampson, J.B. Group problems in extreme environments. Tufts University Human Factors Group, Boston, MA, October 1981.

Sawka, M.N. Physiology of upper body aerobic exercise. Cardiology Section Seminar, Massachusetts Rehabilitation Hospital, Boston, MA, November 1981.

Sawka, M.N. Effect of body water and plasma volume on performance in the heat. Boston University, Boston, MA, February 1982.

Sawka, M.N. Cardiovascular response to environmental changes and to exercise conditioning. MGH Institute of Health Professions, Massachusetts General Hospital, Boston, MA, February 1982.

Sawka, M.N. Exercise and the multiple disability patient. MGH Institute of Health Professions. Massachusetts General Hospital, Boston, MA, March 1982.

Sawka, M.N. Hypohydration and physical work performance. Seminar Series, US Naval Base, New London, CT, May 1982.

Sawka, M.N. Physiology of the female athlete. New England Sports Medicine Institute Program, Massachusetts Maritime Academy, Buzzards Bay, MA, July 1982.

Toner, M.M. Physiological responses to water immersion during rest and exercise. Sargeant College of the Allied Health Professions, Boston University, Boston, MA, 1982.

Vogel, J. Physical fitness research of interest to members of the AMSC. AMSC Research Course, Washington, DC, 9 September 1982.

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APPENDIX G  
MISCELLANEOUS

Sawka, M.N. Visiting Scholar's Award (First Recipient), Presented by the American College of Sports Medicine.

Sawka, M.N. Visiting Assistant Fellow, John B. Pierce Foundation, Yale University School of Medicine.

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